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U.S. Climate Change Technology Program

VISION AND FRAMEWORK FOR STRATEGY AND PLANNING

August 2005

U.S CLIMATE CHANGE TECHNOLOGY PROGRAM

U.S. Department of Energy (Lead-Agency)

U.S. Department of Agriculture

U.S. Department of Commerce, including

National Institute of Standards and Technology

U.S. Department of Defense

U.S. Department of Health and Human Services, including

National Institutes of Health

U.S. Department of Interior

U.S. Department of State, including

U.S. Agency for International Development

U.S. Department of Transportation

U.S. Environmental Protection Agency

National Aeronautics and Space Administration

National Science Foundation

Other Participating Research and Development Agencies

Executive Office of the President, including

Council on Environmental Quality

Office of Science and Technology Policy

Office of Management and Budget

Presidential Leadership for a Long Term Challenge

"I reaffirm America's commitment to the United Nations Framework Convention and its central goal, to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous human interference with the climate."

"(We will) set America on a path to slow the growth of our greenhouse gas emissions and, as science justifies, to stop and then reverse the growth of emissions."

President George W. Bush
February 14, 2002

VISION AND FRAMEWORK FOR STRATEGY AND PLANNING

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Administration Actions to Advance Technologies for Addressing Global Climate Change

I've asked my advisors to consider approaches to reduce greenhouse gas emissions, including those that tap the power of markets, help realize the promise of technology and ensure the widest-possible global participation….Our actions should be measured as we learn more from science and build on it. Our approach must be flexible to adjust to new information and take advantage of new technology. We must always act to ensure continued economic growth and prosperity for our citizens and for citizens throughout the world.

President Bush
June 11, 2001

As a party to the United Nations Framework Convention on Climate Change (UNFCCC),[1] the United States shares with many other countries the UNFCCC's ultimate objective, that is, the stabilization of greenhouse gas (GHG) concentrations[2] in Earth's atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The United States recognizes that meeting this challenge will require a long-term commitment and international cooperation.

Under the leadership of President Bush, the United States has formulated and is now implementing a comprehensive strategy to address this challenge. It is science- and market-based; and encourages innovation, scientific and technology breakthroughs, and global participation. It focuses on reducing emissions, while sustaining economic growth. Growth and the capital it will create are needed to finance investment in cleaner, more efficient technologies.

The longer-term elements of this strategy build on America's strengths in innovation and technology development. They are augmented by near-term policy measures, financial incentives, voluntary and other Federal programs aimed at slowing the growth of U.S. GHG emissions and reducing GHG intensity.[3] Federal programs include the Climate VISION,[4]

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1. The United States ratified the UNFCCC on October 15, 1992, and it entered into force for the United States on March 21, 1994. The United States is not a party to the related Kyoto Protocol.
2. Greenhouse gases (GHGs) are gases in the Earth's atmosphere that may affect the atmosphere's energy balance and contribute to long-term climate change. The most important GHG that arises from human activities is carbon dioxide (CO_2), resulting mainly from the oxidation of carbon-containing fuels, materials or feedstocks; cement manufacture; or other chemical or industrial processes. Other GHGs include methane from landfills, mining, agricultural production, and natural gas systems; nitrous oxide (N_2O) from industrial and agricultural activities; fluorine-containing halogenated substances (e.g., HFCs, PFCs); sulfur hexafluoride (SF6); and other GHGs from industrial sources. Gases falling under the purview of the Montreal Protocol are excluded from this definition of GHGs.
3. Intensity means emissions per unit of economic output. See White House Fact Sheet on Climate Change, http://www.whitehouse.gov/news/releases/2005/05/20050518-4.html.

Climate Leaders,[5] Energy STAR,[6] and SmartWay Transport Partnership[7] programs, which work with industry to voluntarily reduce emissions. The Department of Agriculture has conservation programs, which provide incentives for actions that increase carbon sequestration[8] in trees and soils. Energy efficiency, alternative fuel, renewable and nuclear energy, methane capture, and other GHG reduction programs and financial incentives are also underway.

Over the longer term, significant progress would likely require fundamental changes in the way the world produces and uses energy, as well as changes in other processes and infrastructure used in industry, agriculture, forestry, and other human activities that result in GHG emissions. Science should be the guide for how best to address these challenges. Advanced technologies – including those that increase energy efficiency in end-uses; advanced and novel energy supply technologies; CO_2 capture and storage, and carbon sequestration; and technologies to reduce emissions of non-CO_2 GHGs – if successful, could eventually facilitate accelerated progress toward addressing the long-term challenge of climate change, while also continuing the energy-related and other services needed to sustain economic growth.

The United States is committed to leading the development of these new technologies. A detailed strategic plan is currently under development and will be organized around six complementary strategic goals reflecting these opportunities. The first five are focused on developing technologies to (i) reduce emissions from energy end-use and infrastructure; (ii) reduce emissions from energy supply, particularly by development and commercialization of no- or low-emission technologies; (iii) capture, store and sequester CO_2; (iv) reduce emissions of non-CO_2 GHGs; and (v) enhance the measurement and monitoring of GHG emissions. Supporting all of the above is the sixth goal to (vi) strengthen the contributions of basic science to climate change technology development.

This *Vision and Framework* provides overall planning guidance and strategic direction, with goals, for Federal agencies contributing to climate change-related technology research and development. It establishes a framework of principles and approaches to be employed toward goal attainment. It defines criteria for inclusion of applicable research, development, demonstration and deployment (collectively referred to here as R&D) of GHG-related activities, identifies the current R&D portfolio of such activities, and establishes criteria for future portfolio planning and investment prioritization. Finally, it outlines a series of "next steps" that will guide future Federal activities in this area over the coming years.

4 See http://www.climatevision.gov.
5 See http://www.epa.gov/climateleaders.
6 See http://www.energystar.gov.
7 See http://www.epa.gov/smartway.
8 See http://www.usda.gov/news/releases/2003/06/fs-0194.htm.

U.S. Leadership and Presidential Commitment

On June 11, 2001, the President launched the National Climate Change Technology Initiative.[9] Backed by unprecedented levels of Federal investment in climate change-related R&D, the Presidential initiative signaled Federal leadership in climate change technology development. Through partnering with others, the initiative aims to stimulate American innovation, strengthen associated research and education, and position the United States as a world leader in pursuit of advanced technologies that could help meet this global challenge. The President said:

[W]e're creating the National Climate Change Technology Initiative to strengthen research at universities and national labs, to enhance partnerships in applied research, to develop improved technology for measuring and monitoring gross and net greenhouse gas emissions, and to fund demonstration projects for cutting-edge technologies.

In January 2002, the President reorganized Federal oversight, management and administrative control of climate change-related activities.[10] He established a Cabinet-level Committee on Climate Change Science and Technology Integration (CCCSTI), thereby directly engaging the heads of all relevant departments and agencies in guiding and directing these activities. The President directed that innovative approaches be developed in accord with a number of basic principles:

(1) be consistent with the long-term goal of stabilizing GHG concentrations in the atmosphere;

(2) be measured, as more is learned from science, and build on it;

(3) be flexible to adjust to new information and take advantage of new technology;

(4) ensure continued economic growth and prosperity;

(5) pursue market-based incentives and spur technological innovation; and

(6) base efforts on global participation, including developing countries.

The CCCSTI makes recommendations to the President on matters concerning climate change science and technology plans, investments and progress.

Secretary of Energy Samuel W. Bodman is Chair of the Cabinet-level Committee on Climate Change Science and Technology Integration. The Chair alternates annually between the Secretaries of Energy and Commerce.

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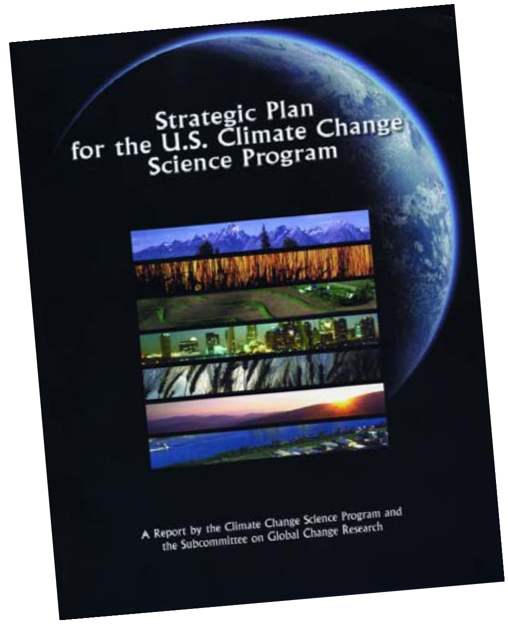
[9] White House Rose Garden speech www.whitehouse.gov/news/releases/2001/06/20010611-2.html. The Initiative was a significant step in implementing a recommendation approved by the President in May 2001 as part of the National Energy Policy, which called for the President to "direct federal agencies to support continued research into global climate change; continue efforts to identify environmentally and cost-effective ways to use market mechanisms and incentives; continue development of new technologies; and cooperate with allies, including through international processes, to develop technologies, market-based incentives, and other innovative approaches to address the issue of global climate change."

[10] See http://www.whitehouse.gov/news/releases/2003/09/20030930-11.html.

Under the auspices of the CCCSTI, two multi-agency programs were established to coordinate and integrate Federal activities, review progress and make recommendations. These are known respectively as the U.S. Climate Change Science Program, led by the U.S. Department of Commerce, and the U.S. Climate Change Technology Program, led by the U.S. Department of Energy (Figure 1).



U.S. Climate Change Science Program

The U.S. Climate Change Science Program (CCSP)[11] is an interagency research planning and coordinating entity. It is responsible for facilitating the development of a strategic approach to Federally supported climate research, integrated across the participating agencies. Its principal aims are to investigate natural and human-induced changes in the Earth's global environmental system, monitor important climate parameters, predict global change, and provide a sound scientific basis for national and international decision-making. Figure 1 shows that it operates under the direction of the Assistant Secretary of Commerce for Oceans and Atmosphere. It reports through the Interagency Working Group (IWG) on Climate Change Science and Technology, composed of agency deputies, to the CCCSTI.

Regarding climate change science, on May 11, 2001, the President asked the National Research Council (NRC)[12] to examine the state of knowledge and understanding of climate change. The resulting NRC report[13] concluded that "the changes observed over the last several decades are likely mostly due to human activities, but we cannot rule out that some significant part of these changes is also a reflection of natural variability." The report also noted that there are still major gaps in our ability to measure the impacts of GHGs on the climate system. Major advances in understanding of the climate system, modeling of the factors that influence atmospheric concentrations of GHGs and aerosols, as well as the feedbacks that govern climate sensitivity, are needed to predict future climate change with greater confidence.

In July 2003, CCSP released its strategic plan for guiding climate research.[14] The plan is organized around five goals: (i) improving our knowledge of climate history and variability; (ii) improving our ability to quantify factors that affect climate; (iii) reducing uncertainty in climate projections; (iv) improving our understanding of the sensitivity and adaptability of ecosystems and human systems to climate change; and (v) exploring options to manage risks. Annually, the Federal Government spends almost $2 billion on research related to advancing climate change science.

A subsequent NRC review of the CCSP strategic plan concluded that the Administration is on the right track, stating that the plan "articulates a guiding vision, is appropriately ambitious, and is broad in scope." The NRC's report also identified the

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[11] See http://www.climatescience.gov.

[12] The National Research Council (NRC) is the operating arm of the National Academies, which consists of the National Academy of Sciences, the National Academy of Engineering, and the Institutes of Medicine.

[13] National Research Council, Climate Change Science: An Analysis of Some Key Questions, Committee on the Science of Climate Change (Washington, DC: National Academy Press, 2001): 20-21.

[14] See http://www.climatescience.gov/Library/stratplan2003/final/default.htm.

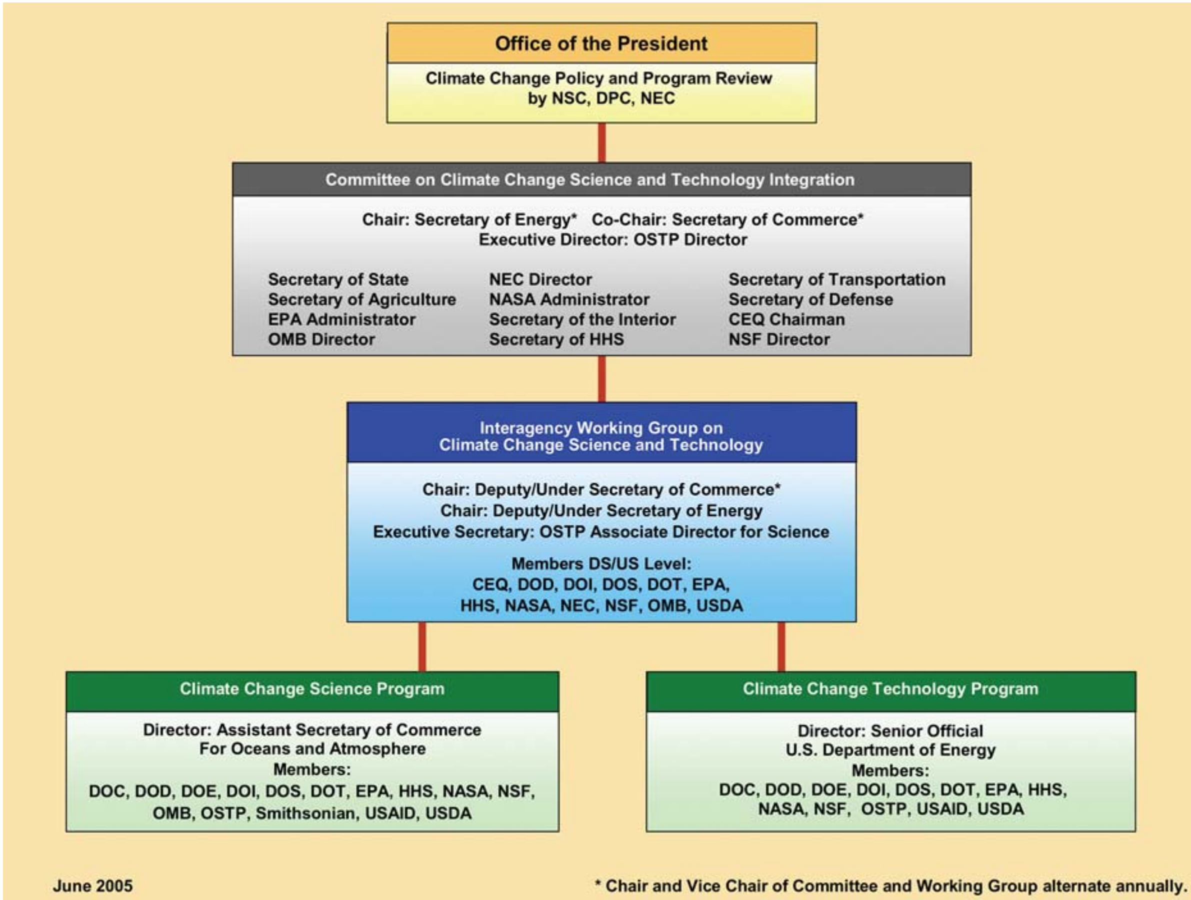

Figure 1: Cabinet-Level Committee on Climate Change Science and Technology Integration

need for a broad global observation system to support measurements of climate variables.

In June 2003, the United States hosted more than 30 nations at the inaugural Earth Observation Summit, which resulted in a commitment to establish an intergovernmental, comprehensive, coordinated, and sustained Earth observation system. The data collected by the system will be used for multiple societal benefit areas, including better climate models, improved knowledge of the behavior of CO_2 and aerosols in the atmosphere, and the development of strategies for carbon sequestration.

Since that initial meeting, two additional ministerial summits have been held, and the intergovernmental partnership has grown to nearly 60 nations. At the most recent meeting, Earth Observation Summit III in Brussels, a Ten-Year Implementation Plan for the Global Earth Observation System of Systems (GEOSS) was adopted, and the intergovernmental Group on Earth Observations was established to begin

[15] National Research Council, Implementing Climate and Global Change Research: A Review of the Final U.S. Climate Change Science Program Strategic Plan (Washington, DC: National Academies Press 2004): 1.

[16] See http://iwgeo.ssc.nasa.gov.

[17] See http://www.climatetechnology.gov.

implementation of the 2-, 6-, and 10- year targets identified in the plan. The U.S. contribution to GEOSS is the Integrated Earth Observation System (IEOS). In April 2005, the USG Committee on Environment and Natural Resources (CENR) released the *Strategic Plan for the U.S. Integrated Earth Observation System*[16] that addresses the policy, technical, fiscal, and societal benefit components of this integrated system and established the U.S. Group on Earth Observation (USGEO).

U.S. Climate Change Technology Program

The U.S. Climate Change Technology Program (CCTP)[17] is the technology counterpart to CCSP. It is a multi-agency planning and coordinating entity, led by the Department of Energy. The CCTP's principal aim is to accelerate the development of new and advanced technologies to address climate change. The CCTP works with participating agencies (Table 1), provides strategic direction for the CCTP-related elements of the overall Federal R&D portfolio, and facilitates the coordinated planning, programming, budgeting and implementation of the technology development and deployment aspects of U.S. climate change strategy. The CCTP operates under the direction of a senior-level official at the Department of Energy and reports through the IWG to the cabinet-level CCCSTI.

[16] See http://iwgeo.ssc.nasa.gov.
[17] See http://www.climatetechnology.gov.

AGENCY	SELECTED EXAMPLES OF CLIMATE CHANGE-RELATED TECHNOLOGY R&D PROGRAMS
USDA	Carbon Fluxes in Soils, Forests and Other Vegetation, Carbon Sequestration, Nutrient Management, Cropping Systems, Forest and Forest Products Management, Livestock, and Waste Management, Biomass Energy and Bio-based Products Development
DOC	Instrumentation, Standards, Ocean Sequestration, Decision Support Tools
DOD	Aircraft, Engines, Fuels, Trucks, Equipment, Power, Fuel Cells, Lasers, Energy Management, Basic Research
DOE	Energy Efficiency, Renewable Energy, Nuclear Fission and Fusion, Fossil Fuels and Power, Carbon Sequestration, Basic Energy Sciences, Hydrogen, Bio-Fuels, Electric Grid and Infrastructure
HHS*	Environmental Sciences, Biotechnology, Genome Sequencing, Health Effects
DOI	Land, Forest, and Prairie Management, Mining, Sequestration, Geothermal Energy, Terrestrial Sequestration Technology Development
DOS*	International Science and Technology Cooperation, Oceans, Environment
DOT	Aviation, Highways, Rail, Freight, Maritime, Urban Mass Transit, Transportation Systems, Efficiency and Safety
EPA	Mitigation of CO_2 and Non-CO_2 GHG Emissions through Voluntary Partnership Programs, including Energy STAR, Climate Leaders, Green Power, Combined Heat and Power, State and Local Clean Energy, Methane and High-GWP Gases, and Transportation; GHG Emissions Inventory
NASA	Earth Observations, Measuring, Monitoring, Aviation Equipment, Operations and Infrastructure Efficiency
NSF	Geosciences, Oceans, Nanoscale Science and Engineering, Computational Sciences
USAID*	International Assistance, Technology Deployment, Land Use, Human Impacts

** CCTP-related funding for the indicated agencies is not included in the totals for CCTP in the budget tables of Appendix B. However, the agencies participate in CCTP R&D planning and coordination as members of CCTP's Working Groups. Agency titles for the acronyms above are shown in Appendix B*

Table 1: Federal Agencies Participating in the U.S. Climate Change Technology Program

Vision and Mission

The CCTP strives, through the R&D programs of its participating agencies, to provide Federal leadership in climate change technology development. Through its plans, partnerships, and research progress, the CCTP hopes to stimulate innovation more broadly, outside the Federal community, and inspire private sector interest and enhanced international cooperation in the global quest to develop, commercialize and employ such technology to reduce GHG emissions. Accordingly, the vision and mission of the CCTP are as follows.

CCTP Vision

The CCTP vision is to attain on a global scale, in partnership with others, a technological capability that can provide abundant, clean, secure, and affordable energy and related services needed to encourage and sustain economic growth, while simultaneously achieving substantial reductions in emissions of greenhouse gases and mitigating the risks of potential climate change.

CCTP Mission

The CCTP mission is to stimulate and strengthen the scientific and technological enterprise of the United States, through improved coordination and prioritization of multi-agency Federal climate change technology R&D programs and investments, and to provide global leadership, in partnership with others, aimed at accelerating development of new and advanced technologies that can attain the CCTP vision.

Planning Context

Over the course of the 21st century, most analyses of human activities related to global climate change project significant increases in both anthropogenic emissions of GHGs and their atmospheric concentrations. The projected increases result primarily from the economic activities associated with population growth and expansion of global development, accompanied by increasing use of fossil fuels, changes in land use, and increases in other GHG-emitting activities of industry, agriculture, and forestry.

Increased global energy use is also needed to help lift out of poverty the nearly 2 billion people who lack even the most basic access to modern energy services. Addressing this "energy poverty" is one of the world's key development objectives, as lack of energy services is associated with high rates of disease and child mortality.

Growing concern over projections of such increases in global greenhouse gas emissions, concentrations, and their potential consequences led 157 countries, in May 1992, to adopt the UNFCCC, or the Framework Convention. President Bush reaffirmed America's commitment to the Framework Convention in 2002. The Framework Convention thus helps to form the context for the longer-term technology development strategies outlined in this CCTP Vision and Framework and, subsequently, for the forthcoming CCTP Strategic Plan.

For the purposes of long-term planning and the guiding of technology research, two considerations arise from the Framework Convention. First, the level of GHG concentrations implied by the Framework Convention's ultimate objective is not yet known and will likely remain a key planning uncertainty for some time. Second, the Framework Convention's ultimate objective, apart from its uncertainty regarding levels, implies an ambitious goal for technology. Stabilizing GHG concentrations at any atmospheric concentration level implies that global *additions* of GHGs to the atmosphere, and global *withdrawals* of GHGs from the atmosphere must come into balance. This means that the growth of net emissions of GHGs would need to slow, eventually peak, and decline, such that net emissions ultimately would approach levels that are low or near zero.

The Role of Technology

Given sufficient effort, time and motivation, aided by visionary leadership, international cooperation, and well-guided research, technological innovations could contribute significantly to this long-term objective, and at the same time promote global economic development and prosperity. Analyses documented in the literature show that accelerated advances in technology have the potential, under certain assumptions, to significantly reduce the cost of mitigation over the course of the 21st century, compared to what would otherwise be the case with usual advances in technology.[18] These technologies will create many new opportunities for both reducing GHG emissions and promoting economic growth.

The CCTP aims to achieve a balanced and diversified portfolio of advanced technology R&D, focusing on energy-efficiency enhancements; low-GHG-emission energy supply technologies; carbon capture, storage, and sequestration methods; and technologies to reduce emissions of non-CO_2 gases. Conducting this R&D will help resolve the technological uncertainties and improve the prospects that the technologies can

[18] For example, see Battelle, *Global Energy Technology Strategy: Addressing Climate Change.* (Washington, DC: Battelle, 2000) and Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios (Cambridge, UK: Cambridge University Press, 2000).

be adapted to market realities, better positioning them for market acceptance and broadbased deployment.

In this way, the CCTP complements the CCSP. Over time, advances in climate change science under CCSP can be expected to improve understanding about climate change and its impacts. Uncertainties about causes and effects of climate change will be reduced and the potential benefits and risks of various courses of future action will become clearer. Similarly, advances in climate change technology under the CCTP can be expected to bring forth an array of advanced technology options that will meet the needs of society, reduce GHG emissions, and cost less. The role of technology, therefore, is to complement the expanding knowledge of climate change science, and provide the means for enabling and facilitating progress toward long-term stabilization goals.

Two publications issued by the CCTP provide more information about the technologies in the portfolio.[19] *The Research and Current Activities* report provides an overview of the science, technology, and policy initiatives that make up the Administration's climate change technology strategy. Readers interested in learning more about the technologies themselves may consult the report, *Technology Options for the Near and Long Term*. As these publications evidence, the United States has already embarked on the world's most ambitious effort to develop advanced technology related to climate change mitigation.

CCTP's goals are not based on any specific level of stabilized GHG concentration. Further scientific research is required to determine the level that would prevent dangerous anthropogenic interference with the climate system.

Strategic Goals

This Vision and Framework outlines six strategic goals that will guide the CCTP strategy planning and interagency coordination. In light of these goals, each participating CCTP agency will review its current R&D portfolio and, to the extent that agency missions and other priorities allow, organize its future R&D portfolio consistent with and supportive of one or more of these six CCTP strategic goals.

[19] Both documents are available at http://www.climatetechnology.gov.

CCTP GOAL 1:

Reduce Emissions from Energy End-Use and Infrastructure

Major sources of anthropogenic carbon-dioxide (CO_2) emissions are closely tied to the use of energy in transportation, residential and commercial buildings, industrial processes, and associated infrastructure. Improving energy efficiency and reducing GHG-emissions intensity in these economic sectors through a variety of technical advances and process changes present large opportunities to decrease overall GHG emissions. Accelerated development of new and advanced technologies in these areas, coupled with accelerated deployment activities, including voluntary, partnership, and assistance programs, can facilitate the realization of these opportunities.

In addition, the application of advanced technology to the electricity transmission and distribution (T&D) infrastructure (the "grid") can have favorable effects on reducing GHG emissions. First, there is a direct contribution to energy and CO_2 reductions resulting from increased efficiency in the transmission and distribution system itself. Second, there can be indirect contributions, through modernizing systems, accomplished by enabling the expanded use of low-emission and/or distributed electricity generating technologies (such as wind, cogeneration of heat and power, and solar power) and the better management of system-wide energy supply and demand. Emissions reduction from energy efficiency gains and reduced energy use could be among the most important contributors to strategies aimed at overall carbon dioxide emissions reduction.

Four types of technological advancements are applicable to this goal:

- **Efficiency, Infrastructure, and Equipment.** Development and increased use of highly efficient motor vehicles and transportation systems, buildings equipment and envelopes, and industrial combustion and process technology can significantly reduce CO_2 emissions, avoid other kinds of environmental impacts, and reduce the life-cycle costs of delivering the desired products and services.
- **Transition Technologies.** So-called "transition" technologies, such as high-efficiency natural-gas-fired power plants, are not completely free of GHG emissions, but are capable of achieving significant reductions of GHG emissions in the near and mid terms by significantly improving or displacing higher GHG-emitting technologies in use today. Ideally, transition technologies would also be compatible with more advanced GHG-free technologies that would follow in the future.
- **Enabling Technologies.** Enabling technologies contribute indirectly to the reduction of GHG emissions by making the development and use of other important technologies possible. For example, a modernized electricity grid, described above, is an essential step in enabling the deployment of more advanced end-use and distributed energy resources needed for reducing GHG emissions. Another example is storage technologies for electricity or other energy carriers. An intelligent electricity grid integrated with smart end-use equipment would further raise performance.

◆ **Alternatives to Industrial Processes, Feedstocks, and Materials.** The economic activities in the future economy, including manufacturing, mining, agriculture, construction, and services, will require feedstocks and other material inputs to production. In addition to the energy efficiency improvements discussed above, opportunities for: lowering CO_2 and other GHG emissions from industrial and commercial activities, including concepts for replacing current feedstocks with those produced through processes (or complete resource cycles) that have lower or zero-net GHG emissions (e.g., bio-based feedstocks); reducing the average energy intensity of material inputs; and devel-oping alternatives to current industrial processes and products.

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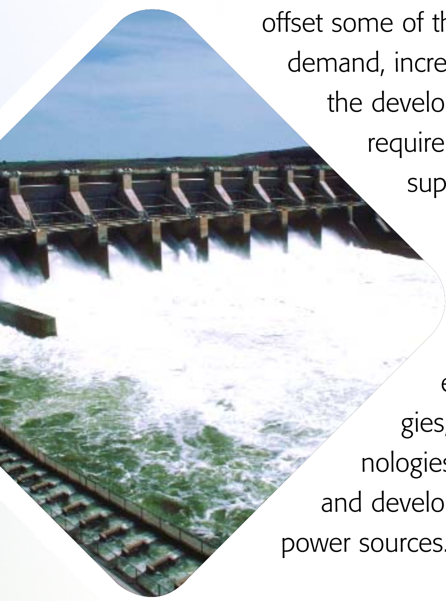
CCTP GOAL 2:

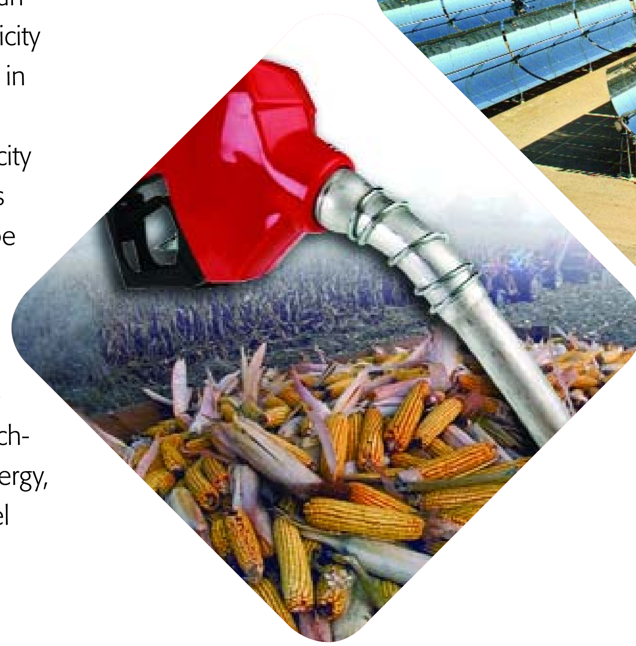
Reduce Emissions from Energy Supply

Current global energy supplies are dominated by the use of fossil fuels – coal, petroleum products, and natural gas – that emit CO_2 when burned. A transition to a low-carbon future would likely require the availability of multiple energy supply technology options characterized by low, near net-zero, or zero CO_2 emissions. Many such energy supply technologies are available today or are under development. Others are being implemented now at increasing rates, with encouragement from Federal programs aimed at spurring deployment through various means. When combined with improved energy carriers (e.g., electricity, hydrogen), these advances offer promising prospects for both reducing GHG emissions and improving overall economic efficiency. The following are examples:

- **Electricity.** Electricity will remain an important energy carrier in the global economy in the future. While substantial improvements in efficiency can offset some of the anticipated growth in electricity demand, increasing electrification, especially in the developing regions of the world, will require significant increases in electricity supply. Reducing GHG emissions from electricity supply could be achieved through further improvements in the efficiency of fossil-based electricity generation technologies, deployment of renewable technologies, increased use of nuclear energy, and development of fusion or other novel power sources.



- **Hydrogen, Bio-Based and Low-Carbon Fuels.** The world economy will have a continuing need for portable, storable energy carriers for heat, power, and transportation. A promising energy carrier is hydrogen, which can be produced in a variety of ways, including carbon-free or low-carbon methods using nuclear, wind, hydroelectric, solar energy, biomass, or fossil fuels combined with carbon capture and sequestration. Hydrogen and other carriers, such as methanol, ethanol, and other low-carbon or bio-based fuels, could serve both as a means for energy storage and as energy carriers in transportation and other applications.



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CCTP GOAL 3:

Capture and Sequester Carbon Dioxide (CO_2)

Fossil fuels will likely remain a mainstay of global energy production well into the 21st century. Transforming fossil fuel-based combustion systems into low or carbon-free energy processes would enable the continued use of the world's plentiful coal and other fossil energy resources. Such a transformation would require further development and application of technologies to capture CO_2 and store it through safe and acceptable means, thus removing it permanently from the atmosphere. There are also large opportunities to remove CO_2 directly from the atmosphere and sequester it on land or in oceans, including increased carbon storage through improved land-use, forest, and agricultural management practices; changes in products and materials; and other means. Two focus areas are important:

- **CO_2 Capture and Storage**. Advanced techniques are under development that could capture CO_2 from such sources as coal-burning power plants, oil refineries, hydrogen production facilities, and various high-emitting industrial processes. Carbon dioxide capture would be linked to geologic storage – permanent storage in geologic formations, such as depleted oil and gas reservoirs, deep coal seams, saline reservoirs, or other deep injection reservoirs.

- **CO_2 Sequestration**. Land-based, biologically assisted means for removing CO_2 from the atmosphere and sequestering it in trees, soils, or other organic materials have proven to be low-cost means for long-term carbon storage. Ocean sequestration may also play a role as a carbon "sink," as science advances the understanding of its efficacy and the potential effects.

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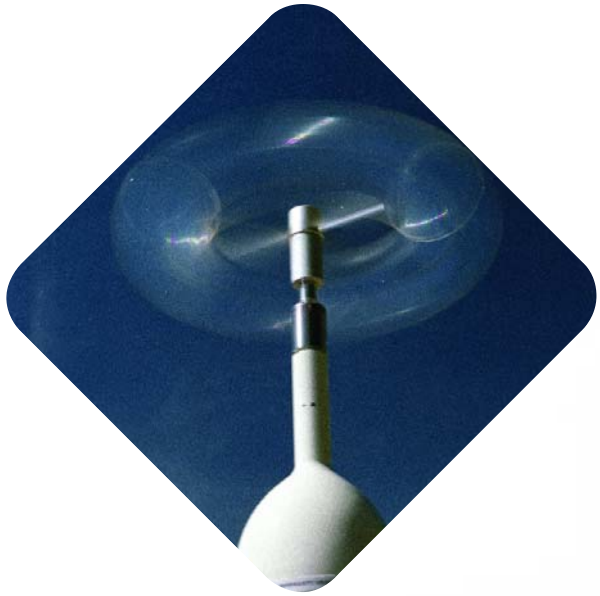
CCTP GOAL 4: Reduce Emissions of Non-CO_2 Greenhouse Gases

GHGs other than carbon dioxide, including methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6) and others are more potent as radiant energy absorbers, per unit weight, than CO_2. In addition, the atmospheric concentration of troposphere ozone, another greenhouse gas, is increasing due to human activities. The Intergovernmental Panel on Climate Change (IPCC) estimated that the cumulative effects of such gases since pre-industrial times account for about 40 percent of the anthropogenic radiative forcing from GHGs. Reducing emissions of these other, non-CO_2 GHGs is an important climate change technology goal and key component of a comprehensive climate change technology strategy. Many categories of technologies are relevant to the attainment of this CCTP goal:

- **Methane Collection and Utilization.** Improvements in methods and technologies to collect methane and detect leaks from various sources, such as landfills, coal mines, natural gas pipelines, and oil and gas exploration operations, can prevent this GHG from escaping to the atmosphere. These methods are often cost-effective, because the collected methane is a fuel that can be used directly or sold in natural gas markets.
- **Reducing N_2O and Methane Emissions from Agriculture**. Improved agricultural management practices and technologies, including application of fertilizers for crop production, livestock waste, and rice production, are key components of the strategy to reduce other GHGs.
- **Reducing Use of High-Global-Warming-Potential (GWP) Gases.** Hydrofluorocarbons and perfluorocarbons have substituted for ozone-depleting chlorofluorocarbons in a number of industries, including refrigeration, air conditioning, foam blowing, solvent cleaning, fire suppression, and aerosol propellants. These and other high-GWP synthetic gases are generally used in applications where they are critical to complex manufacturing processes or provide safety and system reliability, such as in semiconductor manufacturing, electric power transmission and distribution, and magnesium production and casting. Because they are potent GHGs, methods to reduce leakage and use of these chemicals are being explored, as well as the development of lower-GWP alternatives to achieve the same purposes.
- **Black Carbon Aerosols.** Programs aimed at reducing particulate matter have led to significant advances in clean and efficient fuel combustion and emissions control technologies in both transportation and power generation sectors. These advances have reduced and will continue to reduce U.S. black carbon aerosol emissions. Reduced emissions of black carbon, soot, and other chemical aerosols can have multiple benefits, including improved public health and air quality, as well as reduced radiative forcing in the Earth's atmosphere.

[20] Radiative forcing is a measure of the overall net energy balance in the Earth's atmosphere. It is zero when all energy flows in and out of the atmosphere are in balance, or equal. If there is a change in forcing, either positive or negative, it is usually expressed in terms of watts per square meter (W/m^2), averaged over the surface of the Earth. When it is positive, there is a net "force" toward warming, even if the warming itself may be slowed or delayed by other factors, such as the heat-absorbing capacity of the oceans or the energy absorption needed for the melting of natural ice sheets.



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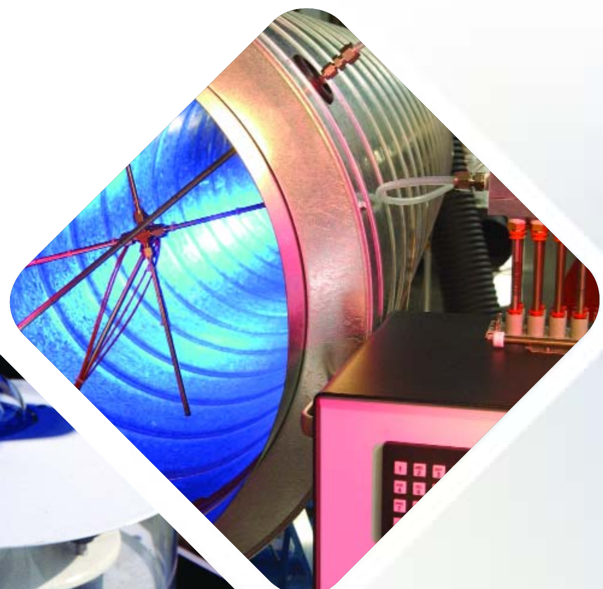
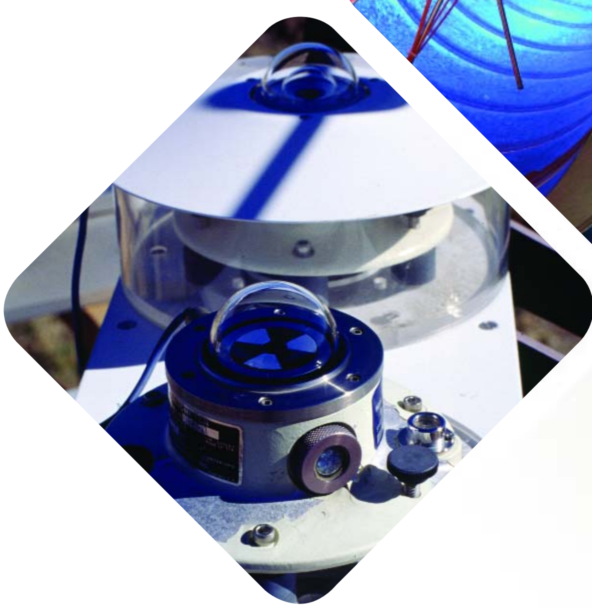
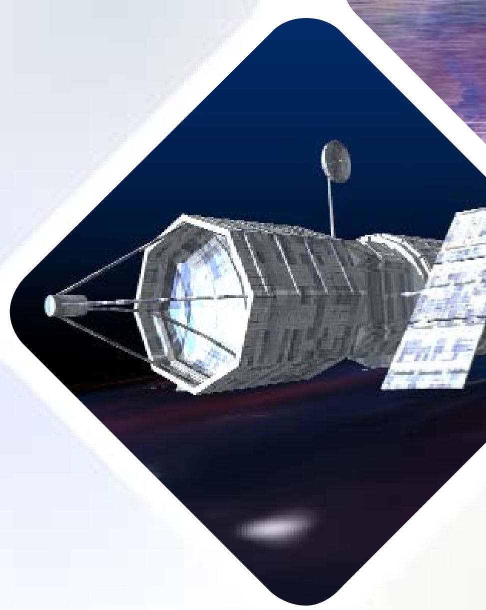


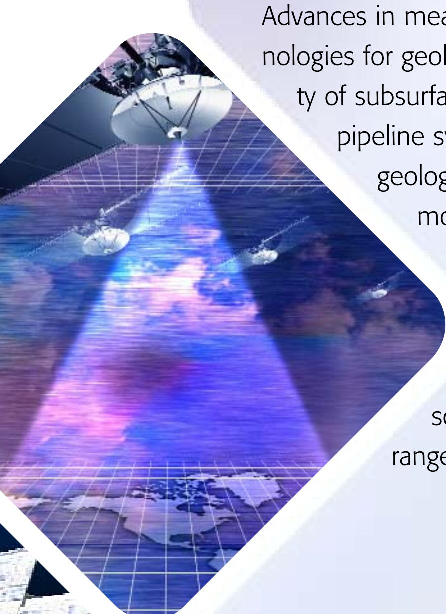




CCTP GOAL 5: Improve Capabilities to Measure and Monitor GHG Emissions

Improved technologies for measuring, estimating, and monitoring GHG emissions and the flows of GHGs across various media and boundaries, will help characterize emission levels and mark progress in reducing emissions. With enhanced means for GHG measuring and monitoring, future strategies to reduce, avoid, capture, or sequester CO_2 and other GHG emissions can be better supported, guided, enabled and evaluated. Key areas of technology R&D related to this goal are grouped into four areas:

- **Anthropogenic Emissions.** Measurement and monitoring technologies can enhance and provide direct and indirect emissions measurements for point and mobile sources using data transmission and archiving, along with inventory-based reporting systems and local-scale atmospheric measurements or indicators.
- **Carbon Capture, Storage and Sequestration.** Advances in measurement and monitoring technologies for geologic storage can assess the integrity of subsurface reservoirs, transportation and pipeline systems, and potential leakage from geologic storage. Measurement and monitoring systems for terrestrial sequestration are also needed to integrate carbon sequestration measurements of different components of the landscape (e.g., soils versus vegetation) across a range of spatial scales.



- **Non-CO_2 Greenhouse Gases**. Monitoring the emissions of methane, nitrous oxide, black carbon aerosols, hydrofluorocarbons, perfluorocarbons, and sulfur hexachloride is important because of their high global warming potential of these GHGs and, for some, the long atmospheric lifetimes. Advanced technologies can make an important contribution to direct and indirect measurement and monitoring approaches for both point and diffused sources of these emissions.
- **Integrated Measuring and Monitoring System Architecture.** An effective measurement and monitoring capability is one that can collect, analyze, and integrate data across spatial and temporal scales, and at many different levels of resolution. This may require technologies such as sensors and continuous emission monitors, protocols for data gathering and analysis, development of emissions accounting methods, and coordination of related basic science and research in collaboration with the Climate Change Science Program and the Integrated Earth Observation System.[21]

[21] See http://iwgeo.ssc.nasa.gov/.

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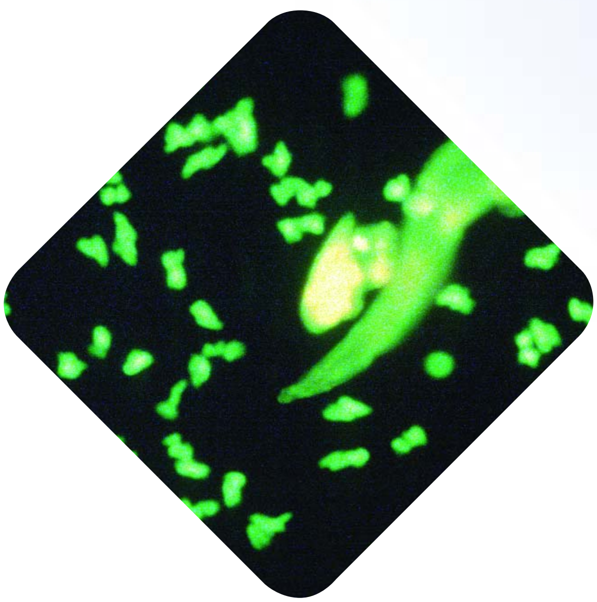


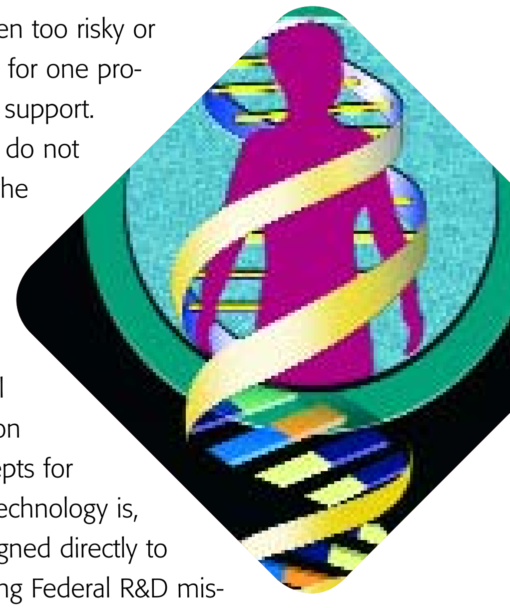
CCTP GOAL 6:

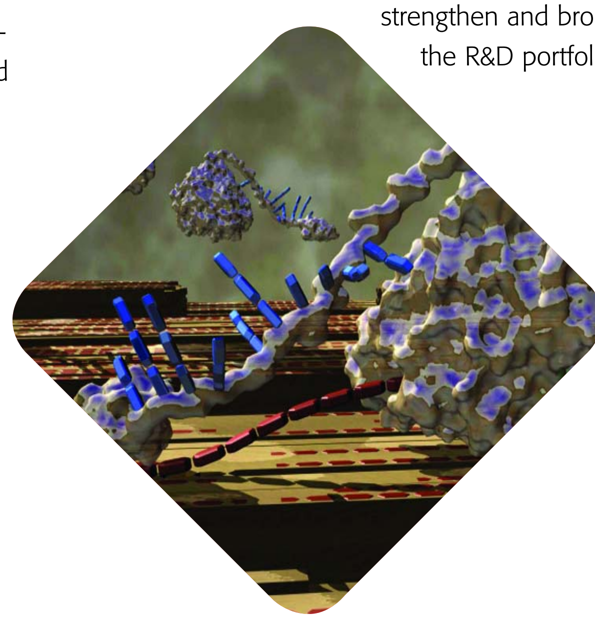
Bolster Basic Science Contributions to Technology Development

Basic scientific research is fundamental to progress in applied technology research and development. The dual challenges—addressing global climate change and providing the energy supply needed to meet future demand, and sustain economic growth—will likely require discoveries and innovations well beyond what today's science and technology can offer. Science must not just inform decisions, but provide the underlying knowledge foundation on which new technologies are built. The CCTP framework aims to strengthen the basic research enterprise so that it will be better prepared to find solutions and create new opportunities. Building on the foundations of fundamental research, CCTP focuses on two ways to meet this goal:

- **Strategic Research.** The CCTP portfolio includes a broad set of ongoing applied technology R&D programs, and more are poised to start in the future. These ongoing and future research activities need to be supported by basic scientific research. Basic research can lead to fundamental discoveries (e.g., new properties, phenomena, or materials) or scientific understanding. Basic research can also be inspired by technical challenges in the applied R&D programs. Results from basic research can then be applied to solving specific problems impeding progress and advancement of technologies in energy supply and end-use, carbon capture, storage and sequestration, non-CO_2 GHGs, and monitoring and measurement.

- **Exploratory Research.** Innovative concepts are often too risky or multi-disciplinary for one program mission to support. Sometimes they do not fit neatly within the constructs of mission-specific program goals. Therefore, not all of the research on innovative concepts for climate-related technology is, or should be, aligned directly to one of the existing Federal R&D mission-related programs. The climate change challenge calls for new breakthroughs in technology that could dramatically reduce GHG emissions or change the way energy is produced, transformed, and used in the global economy. Basic exploratory research of innovative and novel concepts, not elsewhere covered, is one way to uncover such "breakthrough technology" and strengthen and broaden the R&D portfolio.





Core Approaches

The CCTP will employ seven core approaches to stimulate participation by others and ensure progress toward attainment of CCTP strategic goals, as discussed below: (1) strengthen climate change technology R&D; (2) strengthen basic research at universities and Federal research facilities; (3) enhance opportunities for partnerships; (4) increase international cooperation; (5) support cutting-edge technology demonstrations; (6) ensure a viable technology workforce of the future through education and training; and (7) explore and provide, as appropriate, supporting technology policy.

APPROACH 1:

Strengthen Climate Change Technology R&D

The Federal Government is engaged in a wide range of research and technology development and deployment activities that directly or indirectly contribute to meeting the President's climate change goals. In Fiscal Year 2005, the government invested nearly $3 billion in related technology R&D (Appendix B). Strengthening R&D, however, does not necessarily mean spending more money; it means spending more wisely by appropriately prioritizing activities and reallocating resources.

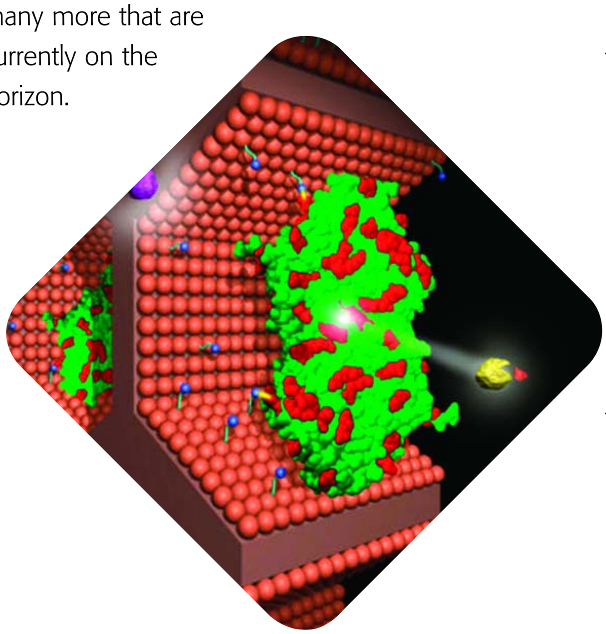
To strengthen the current state of the U.S. climate change technology R&D, the CCTP has made, and will continue to make, recommendations to the Cabinet-level CCCSTI to sharpen the focus of and provide support for climate change technology R&D in a manner consistent with the mix and level of R&D investment required by the nature of the technical challenge.

APPROACH 2:

Strengthen Basic Research Contributions

A base of supporting fundamental research is essential to the applied R&D for technology development. The CCTP approach includes strengthening basic research in Federal research facilities and academia by focusing efforts on key areas needed to develop insights or breakthroughs relevant to climate-related technology R&D. A strong and creative science program is necessary to support and enable technical progress in CCTP's portfolio of applied R&D programs, explore novel approaches to new challenges, and bolster the underlying knowledge base for new discoveries.

Fundamental discoveries can reveal new properties and phenomena that can be applied to development of new energy technologies and other important systems. These can include breakthroughs in our understanding of biological functions, properties and phenomena of nanomaterials and structures, computing architectures and methods, plasma science, environmental sciences, and many more that are currently on the horizon.



APPROACH 3:

Enhance Opportunities for Partnerships

Federal research is but one element of the overall strategy for development and adoption of advanced climate change technologies. Engagement in this process by private entities, including business, industry, agriculture, construction and other sectors of the U.S. economy, as well as by non-Federal governmental entities, such as the States and non-governmental organizations, is essential to help guide R&D investments wisely and to expedite deployment and adoption of innovative and cost-effective approaches for reducing GHG emissions.

Public-private partnerships not only leverage Federal resources, but also facilitate the transfer of technologies from Federal and national laboratories into commercial applications. Partnering can also advise on direction and improve the productivity of Federal research. Private partners also benefit, because those who are engaged in Federal R&D gain rights to intellectual property and access to world-class scientists, engineers, and laboratory facilities. This can help motivate further investment in the commercialization of technology.

Today, partnering is a common mode of operation in most Federal R&D programs, but the partnering process can be improved and further encouraged through a variety of means. Opportunities exist for private participation in virtually every aspect of Federal R&D. CCTP agencies are already engaged in a wide range of active partnerships and related activities that encourage implementation of GHG-reducing measures and technologies. With respect to climate change technology R&D, the CCTP seeks to expand these opportunities in R&D planning, program execution, and technology demonstrations, leading ultimately to more efficient and timely commercial deployment. The Regional Carbon Sequestration Partnerships, initiated by DOE in November 2002, are examples of successful public-private joint efforts.

APPROACH 4:

Increase International Cooperation

Given the global nature of global climate change, and in recognition of the contributions being made by others abroad, the CCTP seeks to engage other nations—government to government—in large-scale cooperative technology research initiatives. Such cooperation can prove beneficial to the success of U.S. technology development initiatives, through leveraging of resources; partitioning of research activities addressing large-scale and multifaceted, complex problems; and sharing of results and knowledge created.

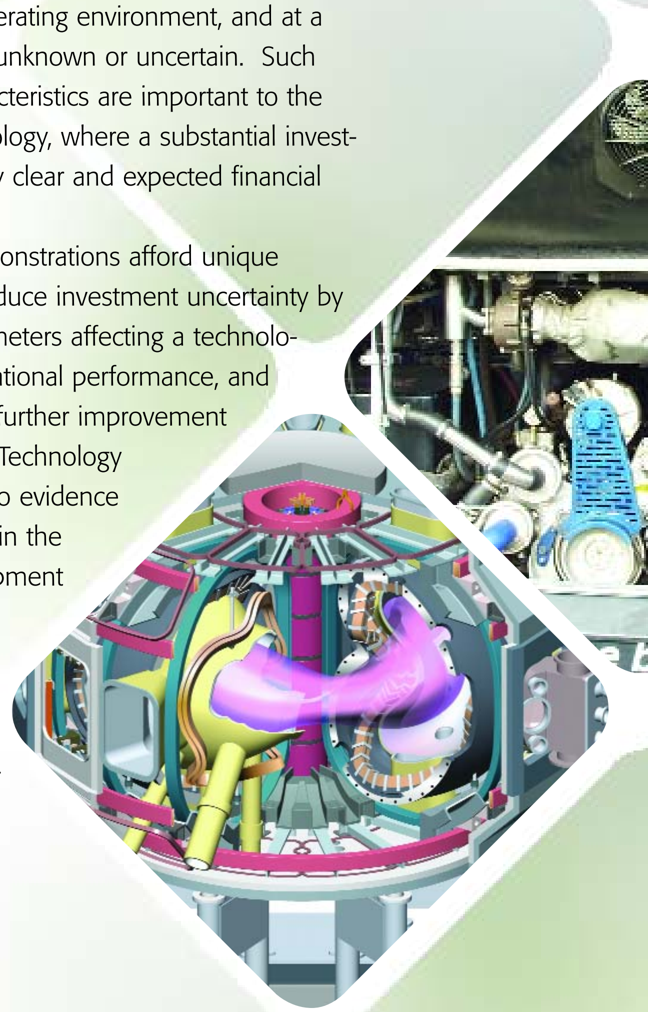
The U.S. Government participates in a variety of multilateral cooperative arrangements that provide a variety of benefits, including the prospect of reducing greenhouse gas emissions. Among these are the Generation IV Nuclear Energy Systems Initiative, International Partnership for a Hydrogen Economy, the international Carbon Sequestration Leadership Forum, the International Methane-to-Markets Partnership, and ITER[22] (an international project to develop fusion as a commercially viable power source.) In certain areas of climate change technology R&D, such as advanced wind turbine design and nuclear fission and fusion energy research, many advanced technical capabilities reside abroad as well as in the United States. Since 2001, the United States has engaged in bilateral partnerships with Australia, Brazil, Canada, China, seven Central American countries, the European Union, India, Italy, Japan, Mexico, New Zealand, Republic of Korea, Russian Federation, and South Africa to explore the next generation of civilian nuclear power technology.

APPROACH 5:

Support Cutting-Edge Technology Demonstrations

Demonstrations of cutting-edge climate change technologies are an important aspect of the goal of advancing climate change technologies. They can help advance a technology's progress from the research phase, where a concept may have been proven in principle or shown to work in the laboratory, but where performance in an operating environment, and at a larger scale, is still unknown or uncertain. Such performance characteristics are important to the viability of a technology, where a substantial investment, motivated by clear and expected financial returns, is required.

Technology demonstrations afford unique opportunities to reduce investment uncertainty by unveiling the parameters affecting a technology's cost and operational performance, and the areas needing further improvement or cost reduction. Technology demonstrations also evidence Federal leadership in the technology development process, which can potentially influence decisions of private-sector investors and other non-government parties.



[22] ITER, International Thermonuclear Experimental Reactor

APPROACH 6:

Ensure a Viable Technology Workforce of the Future

The development and deployment, on a global scale, of new and advanced climate change technologies will require a skilled workforce and an abundance of intellectual talent, well versed in associated concepts and disciplines of science and engineering. Workforce development and education are integral components of any sustained and successful scientific and technological undertaking of this scope and magnitude.

In the current absence of a commercial market for technologies that reduce, avoid, capture or sequester GHG emissions,[23] there is likely to be limited attraction for scientists and engineers to select and seek training in fields specialized for such endeavors. CCTP anticipates a future where such activities will be important. It recognizes that it takes time to attract and train entrants into such fields and nurture the careers, professional experience, skills and competencies required. Workforce development and education, begun in conjunction with CCTP's efforts to develop and deploy the new climate change technologies, would ensure parallel development of the requisite skills and careers.

CCTP's mission and goals provide a unique opportunity to strengthen and revitalize, across all CCTP participating agencies, the current and ongoing Federal investments in science, math, and engineering education, with an additional focus on climate change technology. The technological challenge will attract new talent and ensure the growth of a future workforce knowledgeable and skilled in the needed technical areas.

APPROACH 7:

Provide Supporting Technology Policy

Should widespread adoption of advanced climate change technologies be pursued, as guided by science, it would likely need to be supported by appropriate technology policy. While some CCTP-supported advanced technologies may be sufficiently attractive, for a variety of reasons, to find their way into the marketplace at a large scale without supporting policy or incentives, others would not. Even with further technical progress, technologies that capture or sequester CO_2, for example, or others that afford certain climate change-related advantages, are expected to remain more expensive than competing technologies that do not.

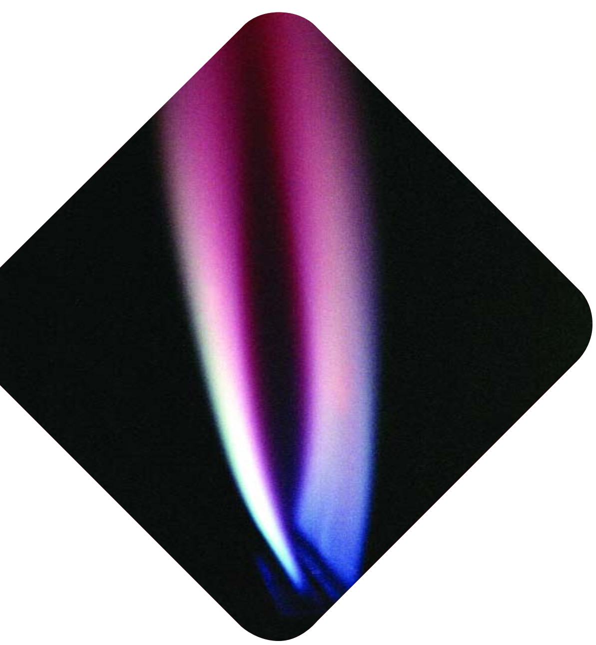
As Federal efforts to advance technology go forward, broadened participation by the private sector in these efforts is important to both the acceleration of innovation and the adoption of the technologies. Such participation, envisioned to extend beyond R&D partnering and demonstrations (Approaches 3 and 5 above), can be encouraged by appropriate and supporting technology policy. This is evidenced today, in part, by a number of tax incentives already in place, and by others proposed by the Administration.[24]

[23] Except for experimental activities in trading GHGs, mostly outside of the United States, there is currently no market or regulatory system that anticipates and internalizes the potential global costs of GHG emissions or the benefits of various courses of mitigating actions. Should such a market develop, it would better signal the professional attractiveness of careers in related fields.

[24] Federal Climate Change Expenditures Report to Congress (March 2005), http://www.whitehouse.gov/omb/legislative/fy06_climate_change_rpt.pdf

Prioritization

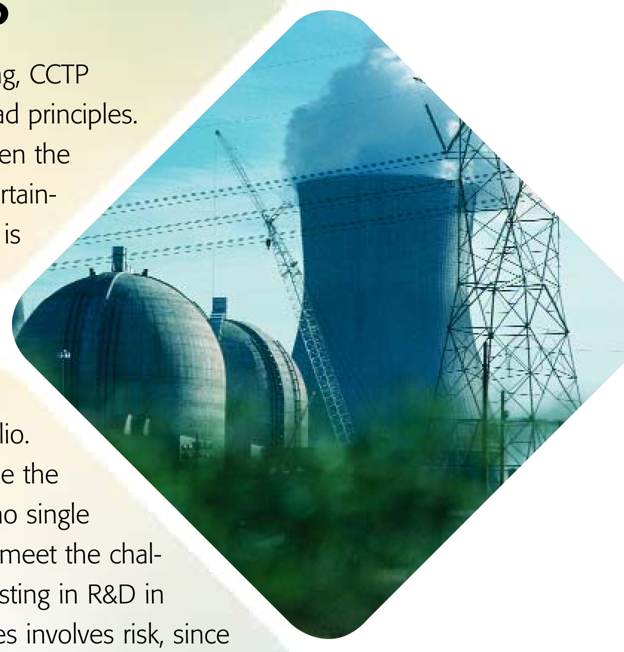
An important role of the CCTP is to provide strategic direction for and strengthen the Federal portfolio of investments in climate change technology R&D. The CCTP continues to prioritize the portfolio of Federally-funded climate change technology R&D consistent with the President's National Climate Change Technology Initiative (NCCTI). In 2005, the CCTP will publish a preliminary Strategic Plan and solicit comments from the scientific community and the public. The CCTP will also identify within its portfolio a subset of NCCTI priority activities, defined as discrete R&D activities that address technological challenges, which, if solved, could advance technologies with the potential to dramatically reduce, avoid, or sequester greenhouse gas emissions.



Strategic Plan

The *CCTP Strategic Plan* (forthcoming) augments the *Vision and Framework* by outlining specific technology strategies for the accomplishment of each of CCTP's strategic goals. The Strategic Plan provides a government-wide basis for guiding and coordinating Federal R&D portfolio planning; identifying high priority investments, gaps and emerging opportunities; and organizing future CCTP-related research. Additionally, CCTP planning activities will be informed by studies, inputs from diverse sources, technical workshops, assessments of technology potentials, analyses regarding long-term energy and emissions outlooks, and modeling by a number of expert groups of a range of technology scenarios over a century-long planning horizon. See Appendix A.

Portfolio Planning Principles



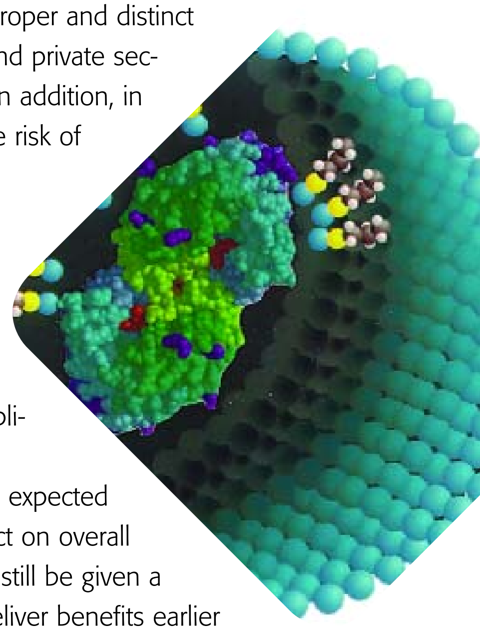
In portfolio planning, CCTP adheres to three broad principles. The first principle, given the many attendant uncertainties about the future, is that the whole of the individual R&D investments should constitute a balanced and diversified portfolio. Considerations include the realizations that (1) no single technology will likely meet the challenge alone; (2) investing in R&D in advanced technologies involves risk, since the results of these investments are not known in advance, and among successful outcomes, some are not likely to be as successful as hoped; and (3) a diverse array of technology options, including related deployment activities, can hedge against risk and provide important flexibility in the future, which may be needed to respond to new and potentially strategy-changing information. The CCTP portfolio also strives to balance short- and long-term technology objectives.

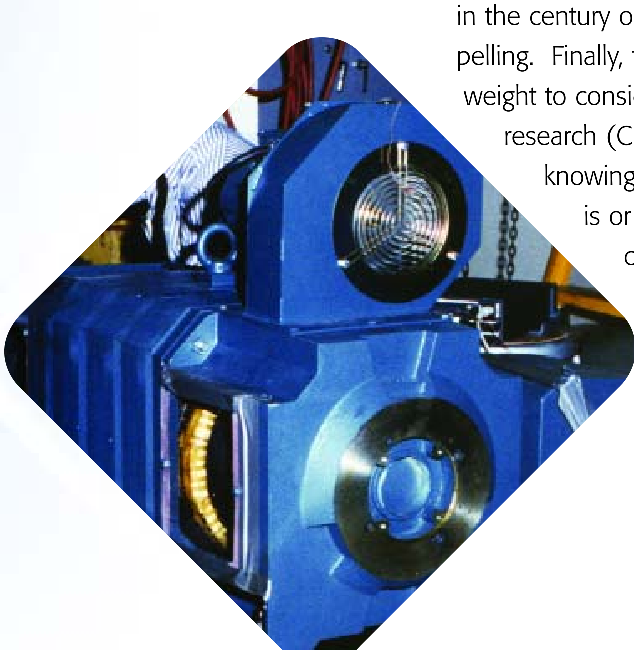
The second principle is to ensure that factors affecting market acceptance are addressed. In order to enable widespread deployment of advanced technologies, each technology must be integrated within a larger technical system and infrastructure. Market acceptance of technologies is influenced by a myriad of social and economic factors. The CCTP's portfolio planning process must be informed by and benefit from private sector and other non-Federal inputs, examine the lessons of historical analogues for technology acceptance, and apply them as a means to anticipate issues and inform R&D planning.

Third, and perhaps most importantly, the timing regarding the commercial readiness of the advanced technology options is an important CCTP planning consideration. Most infrastructure has a long lifetime, and change in the capital stock occurs slowly. Once new technologies are available, their adoption takes time. Some technologies with low or near net-zero GHG emissions may need to be available and moving into the marketplace decades before their maximum market penetration is achieved.

Portfolio Planning and Investment Criteria

Within the planning framework of vision, mission, goals, approaches, and portfolio investment principles, the CCTP's prioritization process applies four criteria (see Box 1, page 28). Once the individual competing investments are identified, the CCTP will then consider their merits based on expected benefits versus costs, such as maximizing potential climate change related benefits per dollar of Federal investment (Criterion #1). CCTP also recognizes the proper and distinct roles for the public and private sectors (Criterion #2). In addition, in order to minimize the risk of portfolio dilution (i.e., spreading resources across too many areas), the CCTP will focus on technologies with potential for large-scale application (Criterion #3). Technologies that are expected to have limited impact on overall GHG emissions may still be given a priority, if they can deliver benefits earlier in the century or are particularly cost-compelling. Finally, the CCTP planning process gives weight to considerations of logical sequencing of research (Criterion #4), where the value in knowing whether a technological advance is or is not successful can have a cascading effect on the sequencing of subsequent investments.





CCTP PORTFOLIO PLANNING AND INVESTMENT CRITERIA

1. Maximizing Return on Investment. R&D investments that provide the greatest likelihood of maximum climate change related benefits per dollar of Federal investment receive priority in investment planning. Benefits are defined with respect to expected contributions to the attainment of CCTP goals and may include other considerations, such as improved productivity and cost savings. Potential climate change benefits are long-term public goods. Discount rates must be appropriate to properly assess alternative technology strategies for achieving both near-term and long-term goals. This criterion includes considerations of development and deployment risks. Projects with high risk, but low emissions-reduction potential should be removed from the CCTP R&D portfolio.

2. Acknowledging the Proper and Distinct Roles for the Public and Private Sectors. The CCTP portfolio recognizes that some R&D is the proper purview of the private sector; other R&D may be best performed jointly through public-private partnerships; and still other R&D may be best performed by the Federal sector alone. In cases where public support of R&D is warranted, technology development and adoption require cooperation and engagement with the private sector. History demonstrates that early involvement in technology R&D by the business community increases the probability of commercialization. A key consideration in the investment process is the means for engaging the talents of the private sector using innovative and effective approaches in both technology development and deployment.

3. Focusing on Technology with Large-Scale Potential. The scope, scale, and magnitude of the long-term climate change challenge suggests that relatively small, incremental improvements in existing technologies will not enable full achievement of CCTP goals. Every technology option has limiting factors of various kinds. Such factors need to be identified, explored and understood early in the planning process. Technology options should be adaptable on a global scale and have a clear path to commercialization. High-priority investments will focus on technology options that could, if successful, result in large mitigation contributions, accumulated over the span of the 21st century. For technologies on the lower end of this criterion, benefits should be deliverable earlier in the century and/or be particularly compelling from a marginal benefit/cost perspective.

4. Sequencing R&D Investments in a Logical, Developmental Order. Investments must be logically sequenced over time. Supporting a robust and diversified portfolio does not mean that all technology options must be supported simultaneously, or that all must proceed at an accelerated pace. Logical sequencing of R&D investments takes into account (i) the expected times when different technologies may need to be made available and cost-effective, (ii) the need for early resolution of critical uncertainties, and (iii) the need to demonstrate early success or feasibility of technologies upon which other technology advancements may be based.

Box 1: CCTP Portfolio Planning and Investment Criteria

Application of Criteria

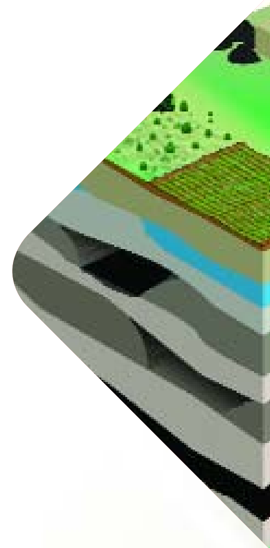
The CCTP's planning and prioritization process will rely on a strategic review of portfolio adequacy to make progress toward attainment of CCTP goals, with an emphasis on identifying gaps, key opportunities for new initiatives, and periodic realignments. The process will not be easily reduced to quantitative analysis due, in part, to the large number of variables and uncertainties associated with the nature of the climate change challenge and, in part, to the CCTP's long planning horizon. The process would be incomplete without recognition of the importance of expert judgment and planning insights. Such caveats notwithstanding, the prioritization criteria discussed above will be applied and augmented by inputs from various quarters.

A first step in the prioritization process, already begun, is to establish a baseline, or inventory, of the existing portfolio of R&D activities across the participating agencies. Criteria for inclusion have been developed. These criteria closely track the CCTP strategic goals. See Appendix B for the budget details and for a list of the inclusion criteria

(not to be confused with the criteria for investment prioritization). The results of this first step are continuing to be refined.

The second step in the process is to assess regularly the potential for each activity in the portfolio to make progress toward accomplishment of the CCTP's strategic goals. This assessment is intended to affirm some elements of the portfolio, challenge others, as well as to identify gaps and promising new opportunities. Once a full set of candidate investments are identified, including gaps and opportunities, the prioritization criteria can then be applied within the context of each strategic goal.

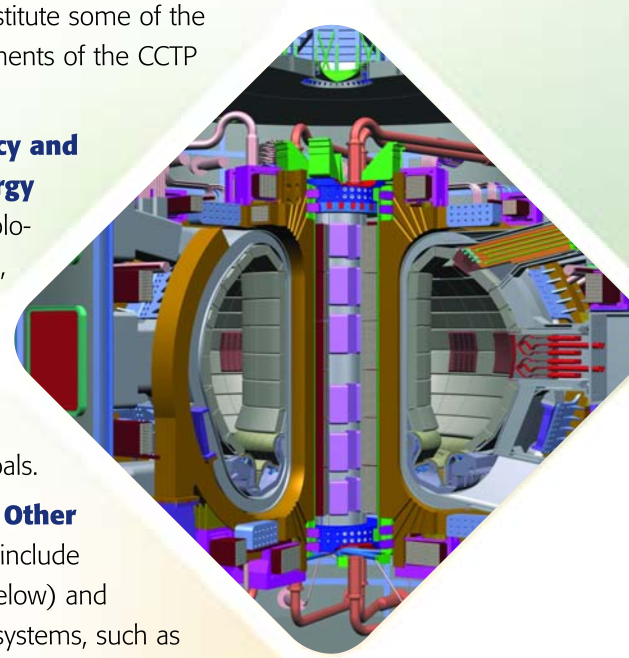
Key Initiatives



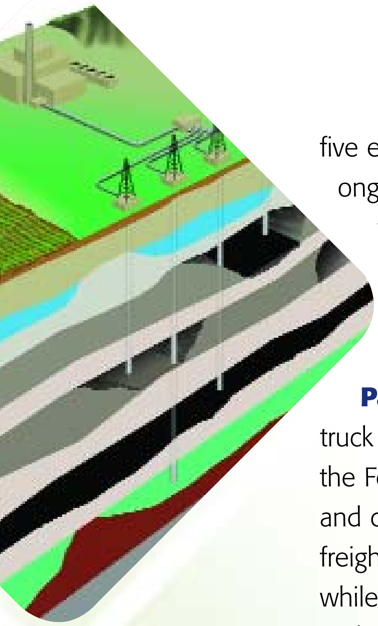
Since early 2002, when the CCTP was first organized, there have been a number of ongoing realignments of the CCTP R&D portfolio. Foremost among these is the identification of key technology initiatives that advance multiple policy goals, such as enhancing energy security, reducing air pollution, and promoting economic growth and productivity, while also addressing important thrusts of CCTP strategic goals. These initiatives complement a core portfolio of supported technologies in energy efficiency, renewable energy, nuclear power, and highly efficient and clean use of coal. The technology initiatives and the research activities of the core portfolio are, in turn, complemented by regional and international partnerships. The key technology initiatives are highlighted below.

- The **Hydrogen Fuel Initiative** focuses on hydrogen production from renewable, nuclear, and fossil sources; storage, safety, and infrastructure for hydrogen; fuel cells; and the underlying basic research. It is closely aligned with the FreedomCAR and Fuel Partnership, listed below.
- **Carbon Sequestration** involves R&D into the capture, transport, storage, and sequestration of CO_2 from fossil fuels, which for decades will likely continue to be the world's most widely used form of energy. It is closely aligned with the FutureGen partnership, listed below.
- **FutureGEN** is a public-private partnership to build world's first emissions-free coal-fired power plant, aimed at demonstrating the viability of a high-efficiency, coal-based electricity generation plant that has the ability to co-produce low-cost hydrogen.
- The **Generation IV Nuclear Energy Systems Initiative** is focused on developing the next-generation fission energy systems, which can offer advances in sustainability, proliferation resistance, physical protection, safety, waste reduction, and cost-effectiveness.
- **ITER** is an international project to develop fusion as a commercially viable power source. The U.S. rejoined ITER in 2003.

Several other important CCTP-related research areas are listed below. Although not identified as key initiatives, these areas, which also serve multiple policy goals, constitute some of the more significant elements of the CCTP core portfolio.



- **Energy Efficiency and Renewable Energy** research in technologies, such as wind, biomass, and solar, can make a substantial contribution to achieving CCTP goals.
- **Clean Coal and Other Power Systems** include FutureGen (see below) and advanced central systems, such as Integrated Gasification and Combined Cycle (IGCC) and the Solid State Energy Conversion Alliance (SECA) for fuel cells.
- The **FreedomCAR and Fuel Partnership** is a collaboration among the DOE, the U.S. Council for Automotive Research (USCAR), and



five energy companies. Working in concert with ongoing hydrogen research, this partnership focuses on the development of fuel cell-powered and other highly efficient transportation vehicles of the future.

- The **21st Century Truck Partnership** is a partnership among U.S. truck manufacturers, supporting industries, and the Federal Government. It is aimed at safely and cost-effectively moving larger volumes of freight and greater numbers of passengers, while dramatically increasing vehicle efficiency and emitting little or no air pollution.
- **Nuclear Power 2010** is a public-private partnership to accelerate the market penetration of new, non-emitting nuclear power plants.

In addition, in order to enhance U.S. activities through both domestic and international outreach, there have been a number of international and regional partnerships established to ensure collaboration on key initiatives and technology research.

- The **International Partnership for the Hydrogen Economy** addresses the technological, financial, and institutional barriers to hydrogen technologies and now involves sixteen countries and the European Commission.
- The international **Carbon Sequestration Leadership Forum,** established in February 2003, coordinates data gathering, R&D and joint projects to advance the development and deployment of carbon sequestration technologies worldwide.

- The domestic **Regional Carbon Sequestration Partnerships** include seven regional partnerships, with state agencies, universities, and private companies forming the core of a nationwide network designed to determine the best approaches for capturing and permanently storing CO_2.
- The international **Methane-to-Markets Partnership**, established jointly in July 2004 by the U.S. Environmental Protection Agency, Department of State, Department of Agriculture, and Department of Energy. It currently has 14 international partners. The Partnership will deliver significant energy, safety, and environmental benefits through the recovery and use of methane, while reducing global GHG emissions. Partners will focus on deploying cost-effective technologies in the near term at landfills, coalmines, and natural gas and oil systems.

- The **Integrated Earth Observation System (IEOS)** is the U.S. contribution to the Global Earth Observation System of Systems, involving nearly 60 countries. IEOS will enable and facilitate sharing, integration and application of global, regional and local data from satellites, ocean buoys, weather stations and other surface and airborne Earth observing instruments. While IEOS serves multiple purposes, one outcome will be the strengthening of U.S. capabilities to measure and monitor GHG emissions and fluxes.

The forthcoming CCTP Strategic Plan will provide a comprehensive basis for review of the portfolio and for identifying additional gaps, opportunities, and high-priority adjustments.

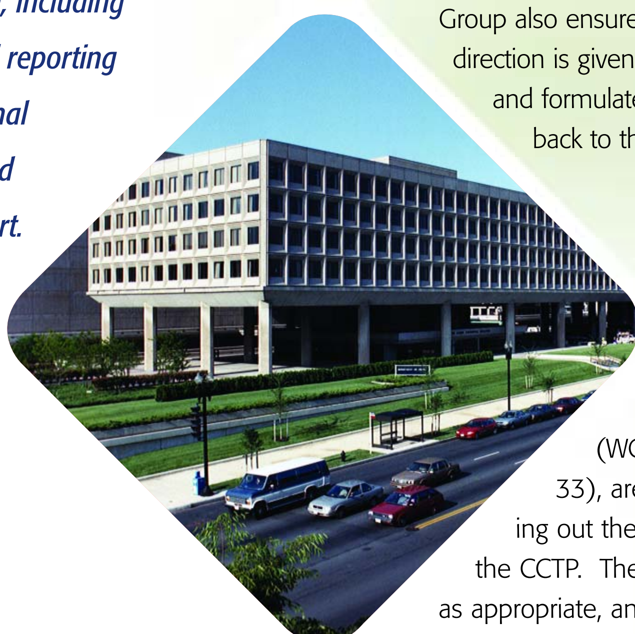
Management

CCTP is a multi-agency, planning and coordination entity that assists the Cabinet leaders of government in carrying out the President's National Climate Change Technology Initiative. In this capacity, CCTP's role is to work with the participating R&D agencies to plan, prioritize, and coordinate related, supporting research, as well as to work with the Administration to formulate budgets and adjust the R&D portfolio as needed to better meet CCTP strategic goals. Discussed below, CCTP's management functions include executive direction; interagency planning, coordination and integration; agency implementation, including monitoring and reporting progress; external interactions; and program support.

Executive Direction

In accord with Figure 1 (page 5), CCTP exercises executive direction through the Cabinet-level CCCSTI and its IWG on Climate Change Science and Technology. The IWG is populated by agency deputies, who are in positions to recommend Cabinet-level approval of coordinated plans and programs and to direct actions that will guide respective agency implementation of those plans and programs.

Executive direction is further facilitated by the CCTP Steering Group. The Steering Group is comprised of senior-level representatives from each participating Federal agency. It ensures that all agencies have a means to raise and resolve issues regarding the CCTP. It functions as a facilitating and coordinating body. The Steering Group assists the CCTP Director in accessing needed information and resources within each agency. The Steering Group is briefed regularly on CCTP plans and activities and assists in developing agency budget crosscuts and proposals, conveying information and actions back to the agencies, and supporting accomplishment of the CCTP mission. The Steering Group also ensures that consistent guidance and direction is given to the CCTP Working Groups, and formulates recommendations and advice back to the CCCSTI, through the IWG.



Interagency Planning and Integration

The CCTP Working Groups (WGs), identified in Box 2 (page 33), are primarily responsible for carrying out the missions and staff functions of the CCTP. The WGs are assisted by subgroups, as appropriate, and by supporting technical staff drawn from the participating agencies, their affiliated laboratories and facilities, and other available expert and consulting staff. The WGs are expected to:

- Serve as the principal means for interagency deliberation and development of CCTP plans and priorities, and the formulation of guidance for supporting analyses in WG's respective areas
- Provide a forum for exchange of inputs and information relevant to planning processes, including workshops and other meetings;
- Engage, cooperate with, and coordinate inputs from the relevant R&D agencies;
- Identify ongoing R&D activities and identify R&D gaps, needs, and opportunities – near- and long-term;
- Support relevant interfaces with CCSP science studies and analyses;
- Formulate advice and recommendations to present to the CCCSTI;
- Assist in the preparation of periodic reports to Cabinet members and the President

Agency Implementation

The CCTP relies on the participating Federal agencies to contribute to CCTP progress and goal accomplishment. CCTP recognizes that agencies must balance CCTP priorities with other mission requirements. However, the CCTP relies on the agencies to place appropriate priority on CCTP program implementation. Priority setting is facilitated by appointing agency heads and deputies to the CCCSTI and IWG. Top agency officials make up the CCTP Steering Group. Agency executives and senior-level managers serve as chairs and members of the CCTP Working Groups. As such, once CCTP plans, programs and priorities are deliberated and set, the agencies are well positioned and prepared to follow through and contribute to execution and completion.

External Interactions

The CCTP accesses expert opinion and technical input from various external parties, through advisory groups, program peer-review processes, conference participation, international partnerships and other activities. In addition, CCTP staff convenes technical workshops and meetings with experts

CCTP WORKING GROUPS

Energy End-Use – Led by DOE
- Hydrogen End-Use
- Transportation
- Buildings
- Industry
- Electric Grid and Infrastructure

Energy Production – Led by DOE
- Hydrogen Production
- Renewable and Low Carbon Fuels
- Renewable Power
- Nuclear Fission Power
- Fusion Energy
- Low Emissions Fossil-Based Power

CO_2 Sequestration – Led by USDA
- Carbon Capture
- Geologic Storage
- Terrestrial Sequestration
- Ocean Storage
- Products and Materials

Other (Non-CO_2) Gases – Led by EPA
- Energy & Waste - Methane
- Agricultural Methane and Other Gases
- High Global-Warming-Potential Gases
- Nitrous Oxide
- Ozone Precursors and Black Carbon

Measuring and Monitoring – Led by NASA
- Application Areas
- Integrated Systems Architecture

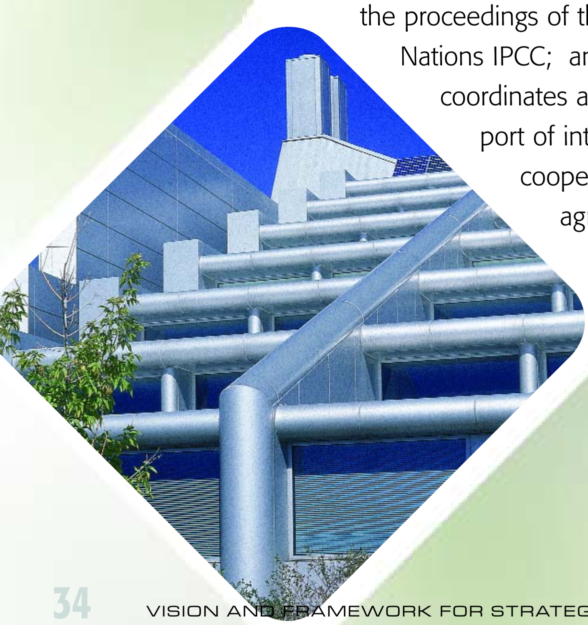
Basic Research – Led by DOE
- Fundamental Research
- Strategic Research
- Exploratory Research
- Integrative Planning Processes

Box 2: CCTP Working Groups

both inside and outside the Federal Government. The CCTP activities are of interest to a number of external parties, including state and local governments, foreign governments, and international organizations, such as the Organization for Economic Cooperation and Development (OECD), the International Energy Agency (IEA), and the IPCC. The CCTP provides coordinated support, through the relevant agency programs, for enhanced international cooperation by engaging with and supporting activities of mutual interest.

Program Support

The CCTP staff provides technical and administrative support and day-to-day coordination of CCTP-wide program integration, strategic planning, product development, communication and representation. The CCTP staff: (1) provides support for the Working Groups and the Steering Group; (2) fosters integration of activities to support the CCTP goals; (3) conducts and supports strategic planning activities that facilitate the prioritization of R&D activities and decision-making on the composition of the CCTP portfolio, including conducting analytical exercises that support planning (such as technology assessments and scenario analysis); (4) develops products that communicate the CCTP's plans, as well as the progress of the CCTP and its Federal participants toward meeting the CCTP goals; (5) coordinates interagency budget planning and reporting; (6) assists and supports the Administration in representing U.S. interests in the proceedings of the United Nations IPCC; and (7) coordinates agency support of international cooperative agreements.



Next Steps

The CCTP's next steps focus on two broad thrusts. First, the CCTP will continue to provide support to the Cabinet-level CCCSTI and IWG on Climate Change Science and Technology. Support will include, but is not limited to, multi-agency planning, portfolio reviews, interagency coordination, technical and other analyses, and formulation of recommendations. The CCTP will strive to provide support that, collectively, will suffice to enable CCCSTI and the IWG to address issues, make informed decisions, and weigh policies and priorities on related science and technology matters to the President and the agencies.

Second, the CCTP will continue to work with and support the participating agencies in developing plans and carrying out activities needed to advance the attainment of the CCTP's vision, mission and strategic goals. For each CCTP strategic goal, to the extent suitable for each goal, agency plans, and activities will be guided by and will pursue the seven core approaches. Selected elements of these approaches are outlined below, although not all elements will be pursued at once.

APPROACH 1:

Strengthen Climate Change Technology R&D

- Continue to review, realign, reprioritize, and expand, where appropriate, Federal support for climate change technology research, development, demonstration, and deployment.

- Periodically assess the adequacy of the multi-agency portfolio with respect to its ability to achieve, or make technical progress toward, CCTP strategic goal attainment; identify gaps, opportunities, and make recommendations.
- In key technology areas, perform long-term assessments of technology potentials, including market considerations and potentially limiting factors.

APPROACH 2:

Strengthen Basic Research Contributions

- Establish or improve within each of the participating Federal R&D agencies a process for the integration with, and application of, basic research to help overcome barriers impeding technical progress on climate change technology development.
- Develop means for expanding participation in climate change technology R&D, including relevant strategic and exploratory research at universities and other non-Federal research institutions.

APPROACH 3:

Enhance Opportunities for Partnerships

- Review status and encourage further formation of public-private partnerships as a common mode of conducting R&D portfolio planning, program execution, and related technology demonstration, transfer, and commercialization activities.

APPROACH 4:

Increase International Cooperation

- Expand international participation in key climate change technology activities; build on the cooperative international initiatives already underway.
- Assist the State Department and CCSP in the coordination of U.S. input and support of the IPCC's periodic assessment reports, especially in areas relating to mitigation; the IPCC special reports such as that on carbon capture and storage; and other relevant activities, as means of stimulating international efforts to develop advanced technologies.
- Support continued efforts to negotiate and execute bilateral agreements that encourage international cooperation on climate change science and technology research and development.
- Pursue additional means to enhance the effective use of existing international organizations, such as OECD, IPCC, IEA, G8, and others, to shape expanded R&D on climate change technology development abroad.
- Develop globally integrated approaches to foster capacity building in developing countries and enable the transfer and development of advanced climate change technology.

APPROACH 5:

Support Cutting-Edge Technology Demonstrations

- As part of the agencies' regular planning and budgeting processes, consider additional cutting-edge technology demonstrations relevant to CCTP strategic goals.

APPROACH 6:

Ensure a Viable Technology Workforce of the Future

- Explore the establishment of graduate fellowships for promising candidates who seek a career in climate-change-related technology R&D.
- Explore possibilities of expanding internships related to climate change technology development in Federal agencies, national and other laboratories, and other Federally Funded Research and Development Centers (FFRDCs).
- Explore possibilities for establishing CCTP-sponsored educational curricula in K-12 programs related to climate change and advanced technology options.

APPROACH 7:

Provide Supporting Technology Policy

- Evaluate various technology policy options for stimulating private sector investment in CCTP-related research, development and experimentation activities.
- Evaluate various technology policy options for stimulating private investment in advanced technology related to climate change or other GHG-related investments, and/or for accelerating the experimentation with and adoption of advanced climate change technology.
- Evaluate various technology policy options for stimulating land-use and land management practices that promote carbon sequestration and GHG emission reductions.

As these approaches are pursued, CCTP's activities will be advised by the CCTP Steering Group, carried out in conjunction with the multi-agency CCTP Working Groups, informed by inputs from varied sources, and supported by CCTP staff and resources. Results will be conveyed to the CCCSTI via the IWG. The CCTP also plans to issue reports, as warranted by ongoing or emerging developments, regarding its current activities, future plans and research progress.

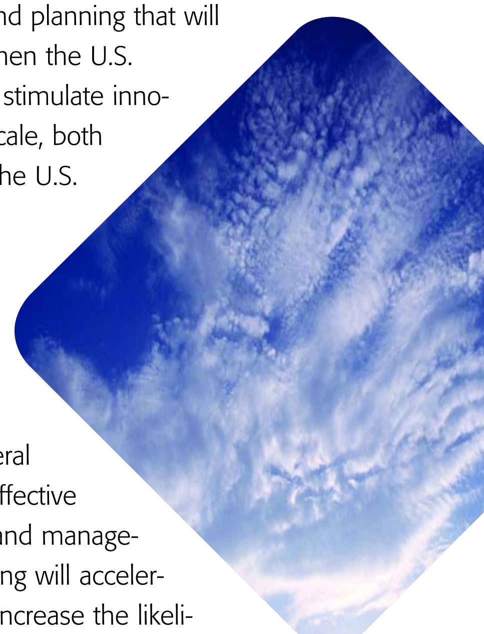
Conclusion

In partnership with others, the United States has embarked on an ambitious undertaking to develop new and advanced climate change technologies that have the potential to transform the economic activities that give rise to GHG emissions. Innovations can be expected to change the ways in which the world produces and uses energy, performs industrial processes, grows crops and livestock, manages carbon dioxide, and uses land.

In keeping with U.S. climate change strategy, which is consistent with the United Nations' Framework Convention, these technologies could both enable and facilitate a gradual shift toward significantly lower global GHG emissions. They would also continue to provide the energy-related and other services needed to spur and sustain economic growth.

With this *Vision and Framework*, CCTP completes an important first step. It articulates a vision for the role of advanced technology in addressing climate change concerns, defines a supporting mission for the multi-agency CCTP, establishes strategic direction for the Federal R&D portfolio within a framework of guiding principles, outlines the approaches to be employed in pursuing attainment of CCTP's six strategic goals, and identifies a series of next steps by which to effect progress on implementation. Importantly, it lays a foundation for a sustained Government-wide R&D coordination and planning that will endeavor to strengthen the U.S. research enterprise, stimulate innovation on a broad scale, both inside and outside the U.S. Government, and encourage others at home and abroad do the same.

With continued Presidential leadership, sustained Federal commitment, and effective CCTP coordination and management, this undertaking will accelerate innovation and increase the likelihood of timely progress. Such progress would go a long way toward securing a bright energy and economic future for our Nation, and for others, while ensuring a healthy planet for future generations.



Appendix A – Summary of Scenarios Analyses and Preliminary Insights

In order to develop plans, carry out activities and help shape a R&D portfolio that will advance the attainment of its vision, mission, and strategic goals, the CCTP needs a long-term planning context, informed by analyses from multiple sources and aided by a variety of decision support tools. An important part of this planning and analytical context is assessing potential contributions that advanced technologies can make to CCTP strategic goals, given a range of assumptions about the future.

Such assessments are complex and subject to many uncertainties. The long-term nature of both climate and technological change, when considered within the context of the UNFCCC's ultimate objective, requires a century-long planning horizon. It also requires a global perspective reflective of changing regional demographics and forecasted patterns of economic activity, which are uncertain. Uncertainties inherent in climate science and associated impacts make it difficult to determine the level at which atmospheric greenhouse gas (GHG) concentrations in the Earth's atmosphere might be considered harmful. Finally, the long-term costs of GHG emission reductions will depend, in part, on future technological innovations, many of which are presently unknown, and on other factors that could either promote or constrain the use of certain technologies in the future.

One approach to planning under conditions of uncertainty is scenarios analysis. Aided by computer simulations, scenarios analyses can explore alternatively imagined technological futures across a range of uncertainties. Such simulations can account for, in a methodical and consistent way, the complex relationships among economic and demographic factors, energy supply and demand, technological change, and emissions. Scenarios analyses can help estimate the costs and benefits of emission reductions under various future conditions, as well as illuminate the complex interactions among the factors that underlie them, based on assumptions incorporated into the analysis. Across many scenarios, such analyses can reveal insights and help characterize elements of proposed strategies either as robust or sensitive to various assumptions. These insights can help inform and guide long-term technology R&D planning.

By clarifying the potential role of climate change technologies under various assumptions about the future, scenarios analyses can support the application of the Portfolio Planning and Investment Criteria (see Box 1, p.28) to the CCTP portfolio. Scenarios analyses can provide a relative indication of the potential climate change benefits for a particular portfolio mix, compared to others. They can help determine which classes of technology would most likely provide larger-scale benefits. Scenarios analyses can help clarify the logical sequence for R&D investments.

Much work has been published in the field of GHG emissions, their projections, and alternative scenarios for their mitigation. The CCTP reviewed about 50 scenarios developed by other organizations, including Shell International,[25] the National

[25] Shell, *Energy Needs, Choices and Possibilities – Scenarios to 2050*. (Shell International Ltd-Global Business Environment Unit, 2001).

Academy of Sciences,[26] the governments of the United Kingdom[27,28] and Canada,[29] the World Business Council for Sustainable Development,[30] and the International Energy Agency (IEA).[31]

In addition, the IPCC developed long-term GHG emission scenarios in mid-1990s and updated them in 2000.[32] More recently, the IPCC's Working Group Report on Mitigation[33] incorporated a set of "Post-SRES" mitigation scenarios, many using the same underlying models that were used for the SRES scenarios.

In carrying out scenarios analyses, a number of assumptions are made regarding the roles and attributes of various types of technology. The review of scenarios analyses published by the IPCC and others revealed that, for the most part, scenarios that achieved significant reductions in future CO_2 emissions had underlying technology assumptions that could be characterized as falling into one of three broad categories:

1. **Scenario #1.** This scenario envisions advanced fossil energy technologies with carbon capture and storage, the introduction of hydrogen as an energy carrier, and high-efficiency energy conversion.
2. **Scenario #2.** This scenario envisions carbon-free energy sources, such as renewable energy (wind power, energy from bio-sources, and other solar energy systems) and nuclear power, expanding over the 21st century, eventually gaining market advantages over traditional fossil fuel-based systems, especially in the electric power sector.
3. **Scenario #3.** This scenario envisions new technologies that significantly change the energy paradigm of the future, including major advances in fusion energy and novel energy applications for solar and Bio-X.[34]

Such scenarios often share some important characteristics. First, most include significant technological advances in end-use energy efficiency, as the cost of implementing efficiency and other energy-saving measures is assumed to decline over time as a result of technological improvement. Many include significant deployment of low-cost terrestrial sequestration and allow for the continued realization of the resource potential of conventional oil and gas. Some recent scenarios also incorporate advanced technologies to reduce emissions of non-CO_2 GHGs from emission sources across all sectors (energy, industry, agriculture, and waste).

Advanced technology scenarios can then be modeled against a range of hypothetical GHG emissions constraints (e.g., low, medium, high, and very high). The results of these, in turn, can be compared against a series of reference or baseline scenarios, where the given GHG emissions con-

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[26] NAS, Our Common Journey: A Transition toward Sustainability. (Washington, DC: National Academy Press, 1999).

[27] *Fuelling the Future – A Report by the Energy Futures Task Force*, (Foresight Programme – Office of Science and Technology, United Kingdom Department of Trade and Industry, 2000).

[28] *Energy for Tomorrow: Powering the 21st Century* (Foresight Programme. Office of Science and Technology. United Kingdom Department of Trade and Industry, 2001).

[29] *Canada 2050, Four Long Term Scenarios for Canada's Energy Future,* (Energy Technology Futures, Natural Resources Canada, 2000).

[30] Energy 2050 – Risky Business (Conches, Switzerland: World Business Council for Sustainable Development, Scenario Unit, 1999).

[31] *Longer Term Energy and Environment Scenarios* (Paris: International Energy Agency Standing Group on Long-Term Co-Operation [IEA/SLT], 2002).

[32] IPCC, *A Special Report on Emissions Scenarios for Working Group III of the Intergovernmental Panel on Climate Change* (IPCC), (Cambridge, UK: Cambridge University Press, 2000). The scenarios presented herein are referred to as "SRES" scenarios.

[33] IPCC, *Climate Change 2001: Mitigation: A Report of Working Group III of the Intergovernmental Panel on Climate Change* (IPCC) (Cambridge, UK: Cambridge University Press, 2001).

[34] "Bio-X" employs combinations of biotechnology, genetic engineering, and nanoscience. It includes novel approaches to the production of hydrogen and other clean fuels, energy carriers and storage media; the production of electricity from bio-sources, the production of biobased alternatives to industrial processes and feedstocks, and bio-processes for carbon dioxide capture and permanent sequestration. Bio-X applications are distinctly different from current energy applications referred to as biofuels, bioenergy or biomass.

straints are met, but with different assumptions about the advancement of technology and costs, compared to the advanced technology scenarios.

While the assumptions in such work are informed by research, and held to be plausible, they are still hypothetical. Thus, caution must be applied in the interpretation of results. Over a range of analyses, however, the results can suggest what might be possible if the hypothetical assumptions could be realized, helping to inform the setting of technical goals for technology R&D programs.

One application of such an analysis was recently completed by the U.S. Department of Energy's Pacific Northwest National Laboratory.[35] The goal of the analysis was not to predict future emissions, or to identify an optimal pathway for climate change technology development, but to gain insights by examining the emissions, energy and economic implications of a range of technology advances, under a range of emissions constraints. Figure A-1, adapted from this analysis, offers one glimpse of the range of emissions reductions new technologies might make possible in energy end-use, energy supply, carbon sequestration, and other GHGs, cumulative over a 100-year scale, across a range of uncertainties. In that regard, the particular scenarios presented here represent an effort to portray current understanding, and are not intended to restrict the future development and use of updated scenarios for program planning purposes. They are included here for illustrative purposes, not to offer a static framework to guide the CCTP program.

From the many scenarios analyses reviewed by CCTP, a number of preliminary insights were drawn about the role of advanced technology in addressing climate change concerns. First, under a wide range of differing assumptions, advanced technologies in energy end-use, energy supply, and carbon sequestration, and controlling emissions of other GHGs could all potentially contribute significantly to overall GHG emissions reductions. No one area is markedly more or less important than others. This suggests the importance of a diversified approach to technology R&D with resources aimed at progress in each area.

Second, reductions in emissions of the non-CO_2 gases could play an important role in reducing overall GHG emissions. Analyses show that decreases of between 10 and 50 percent in methane (CH_4) emissions are possible by mid-century. Similarly, studies show that emissions of nitrous oxide (N_2O) could be reduced by as much as 35 percent by 2100. Successful R&D efforts in the areas of still other GHGs might virtually eliminate emissions of high "global warming potential" chemicals from a number of industrial applications.

Third, scenarios analyses suggest that successful development of advanced technologies could result in potentially large economic benefits, compared to other strategies not so advantaged. Independent of the particular combination of technologies explored, most of the advanced technology scenarios result in significantly lower overall costs, when meeting the range of varying and hypothetical GHG constraints, compared to reference or baseline scenarios.

Finally, scenarios analyses suggest that the timing of the commercial readiness of advanced technology options is an important planning consideration for some of the tighter of the hypothesized GHG emissions constraints. Looking over a 100-year planning horizon, and allowing for capital stock turnover and other inertia inherent in the energy system, technologies with zero or near net-zero GHG emissions would need to be available and moving into the marketplace many years before the emissions "peaks" occur in the hypothetical GHG-constrained cases. Allowing for appropriate

[35] M. Placet, K.K. Humphreys, and N.M. Mahasenan, Climate Change Technology Scenarios: Energy, Emissions and Economic Implications (Washington, DC: Pacific Northwest National Laboratory, August 2004). http://www.pnl.gov/energy/climatetechnology.stm.

lead-in periods, in most of the GHG-constrained cases, new technologies would need to be commercially ready for widespread implementation, should science so justify, between 2020 and 2040. Given time periods for technology development and commercialization, such considerations suggest that the technologies would need to be proven to be technically viable before these times and that initial demonstrations would be needed between 2010 and 2030.

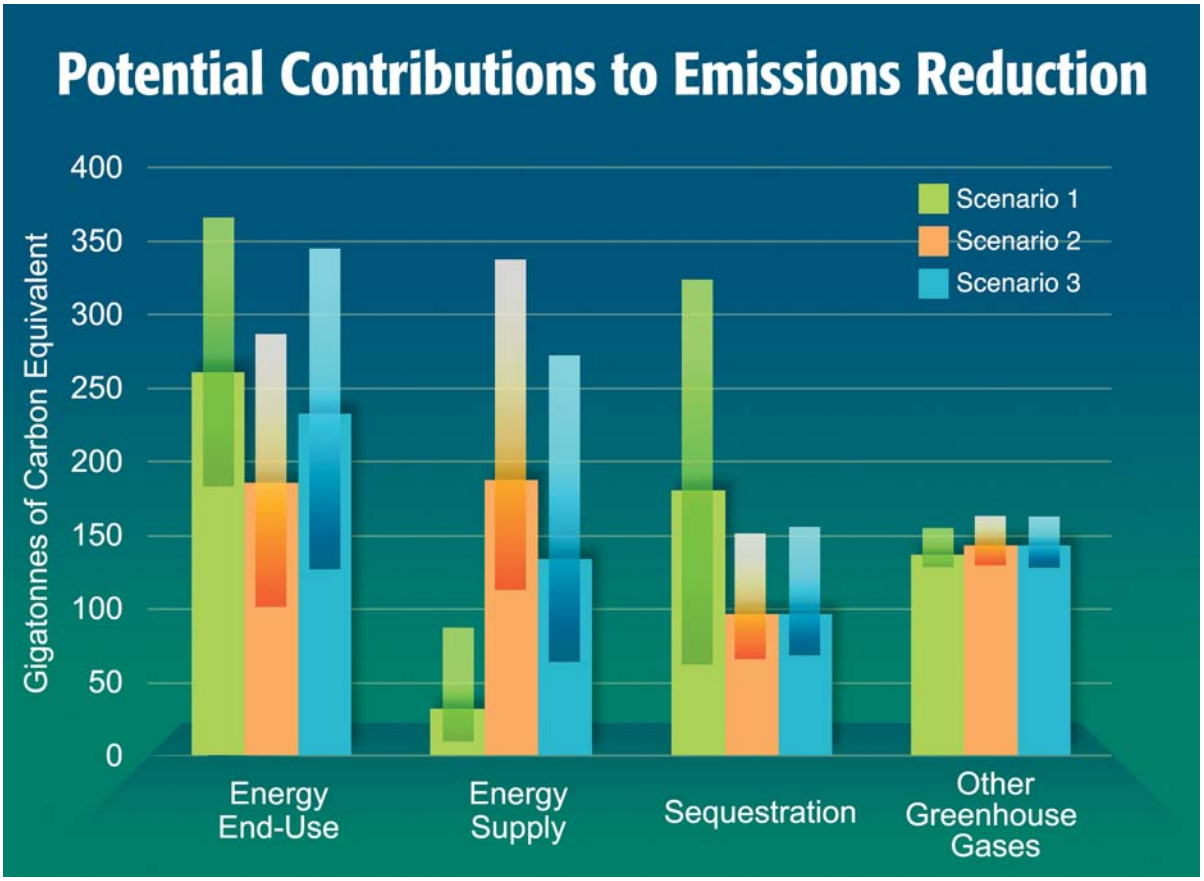

Figure A-1: Potential Ranges of Cumulative Greenhouse Gas Emissions Reductions between 2000 and 2100 Resulting From Advanced Technology Scenarios[36]

[36] The figure shows the cumulative contributions between 2000 and 2100 to the reduction, avoidance, capture/ storage and sequestration of greenhouse gas emissions under the three Advanced Technology Scenarios, based on varying emissions constrained cases. The thick bars show the contribution under the high emission constraint and the thinner, semi-transparent bars show the variation in the contribution between a very high emissions constraint and a low emissions constraint. "Energy End-use" includes emission reductions due to energy efficiency measures. "Energy Supply" includes emissions reductions from the substitution of non-fossil energy supply technologies with low or zero CO_2 emissions for fossil-based power generation without capture and storage of CO_2. "Sequestration" includes carbon capture and storage from fossil-based technologies, as well as terrestrial sequestration.

Appendix B – CCTP Participating Agency FY 2004 to FY 2006 Budgets and Requests

Table B-1: Categorization of R&D Funding To Climate Change Technology Program (Funding, $ Millions)

DEPARTMENT AND ACCOUNT(S)	FY 2004 ACTUAL	FY 2005 ENACTED	FY 2006 PROPOSED (PRELIMINARY)
Department of Agriculture			
Natural Resources Conservation Service – Biomass R&D (Section 9008 Farm Bill)	13.9	14.4	12.4
Natural Resources Conservation Service – Carbon Cycle	0.5	0.5	0.5
Forest Service R&D – inventories of carbon biomass	0.0	0.5	0.5
Agricultural Research Service--Bioenergy Research	2.4	2.4	2.4
Cooperative State Research, Education and Extension Service – Biofuels/Biomass Research; Formula Funds, National Research Initiative	5.4	5.4	6.9
Forest Service – Biofuels/Biomass, Forest and Rangeland Research	0.4	2.4	2.5
Rural Business Service – Renewable Energy Program	22.8	22.8	10.0
Subtotal – USDA	**45.4**	**48.4**	**35.2**
Department of Commerce - NIST			
National Institute of Standards and Technology (NIST) Scientific and Technological Research and Services	9.8	9.5	7.4
Industrial Technical Services – Advanced Technology Program	18.1	20.2	0.0
Subtotal – DOC - NIST	**27.9**	**29.7**	**7.4**
Department of Defense			
Research, Development, Test and Evaluation, Army	15.3	50.5	43.0
Research, Development, Test and Evaluation, Navy	16.5	11.0	7.1
Research, Development, Test and Evaluation, Air Force	0.8	0.8	0.0
Research, Development, Test and Evaluation, Defense-wide	16.8	12.7	9.5
Research, Development, OSD	2.0	0.0	0.0
Subtotal – DOD	**51.5**	**75.0**	**59.6**

Notes:

(1) For EPA, FY 2005 Enacted numbers are for those of the President's FY05 request, not enacted, and that once EPA operating plans are complete, the FY05 numbers will change.

(2) For FY 2006, NASA went through a realignment within its Aeronautics Research. NASA no longer plans to pursue previously reported activities in certain vehicle systems areas.

(3) Totals may not add due to rounding. All agency data are as of March 2005.

(4) USAID activities are not included in the totals for CCTP, but are shown here for completeness, to the extent that such activities are consistent with the criteria for inclusion in CCTP, as shown below.

DEPARTMENT AND ACCOUNT(S)	FY 2004 ACTUAL	FY 2005 ENACTED	FY 2006 PROPOSED (PRELIMINARY)
Department of Energy			
Energy Conservation	868.0	868.2	846.8
Energy Supply/Electricity Transmission & Distribution	73.0	103.0	84.0
Energy Supply/Nuclear	308.7	394.4	416.1
Energy Supply/Renewables	352.3	380.3	353.6
Fossil Energy R&D (Efficiency and Sequestration)	455.0	388.2	405.3
Science (Fusion, Sequestration, and Hydrogen)	332.7	370.6	398.7
Climate Change Technology Program Direction	0.0	0.0	1.0
Subtotal – DOE	**2389.6**	**2504.7**	**2505.5**
Department of the Interior			
US Geological Survey - Surveys, Investigations and Research - Geology Discipline, Energy Program	0.5	2.0	2.0
Subtotal – DOI	**0.5**	**2.0**	**2.0**
Department of Transportation			
Office of the Secretary for Technology - Transportation, Policy, R&D	4.0	0.8	0.0
National Highway Traffic Safety Admin	0.0	0.0	1.4
Research and Innovative Technology Admin	0.5	0.5	1.0
Subtotal – DOT	**4.5**	**1.3**	**2.4**
Environmental Protection Agency (1)			
Environmental Programs and Management	89.8	91.5	95.7
Science and Technology	20.5	17.5	17.7
Subtotal – EPA	**110.3**	**109.0**	**113.4**
National Aeronautics and Space Administration (2)			
Exploration, Science & Aeronautics	226.6	207.8	127.6
Subtotal – NASA	**226.6**	**207.8**	**127.6**
National Science Foundation			
Research and Related Activities	11.2	10.6	11.3
Subtotal – NSF	**11.2**	**10.6**	**11.3**
CCTP Total (3)	**2867.5**	**2988.5**	**2864.5**
USAID Activities Associated with CCTP (4)			
Development and Assistance	173.0	173.0	147.0
Subtotal – USAID	**173.0**	**173.0**	**147.0**
Total CCTP and Associated USAID Activities	**3040.5**	**3161.5**	**3011.5**

Criteria for Including Activities Related to the U.S. Climate Change Technology Program

Research, development, demonstration, and deployment activities[37] classified as being climate change work or associated with the goals and objectives of the Climate Change Technology Program (CCTP) must be activities that are relevant to providing opportunities for:

- Current and future reductions in or avoidances of emissions of GHGs
- GHG capture and/or long-term storage, including biological uptake and storage
- Conversion of GHGs to beneficial use in ways that avoid emissions to the atmosphere
- Monitoring and/or measurement of GHG emissions, inventories, and fluxes in a variety of settings
- Technologies that improve or displace other GHG emitting technologies, such that the result would be reduced GHG emissions compared to technologies they displace
- Technologies that could enable or facilitate the development, deployment, and use of other GHG-emissions reduction technologies
- Technologies that alter, substitute for, or otherwise replace processes, materials, and/or feedstocks, resulting in lower net emission of GHGs
- Technologies that mitigate the effects of climate change, enhance adaptation or resilience to climate change impacts, or potentially counterbalance the likelihood of human-induced climate change
- Basic research activities undertaken explicitly to address a technical barrier to progress of one of the above climate change technologies
- GHG emission reductions resulting from clear improvements in management practices or purchasing decisions

Specific examples of climate change technology activities include, but are not limited to

- Electricity production technologies and associated fuel cycles with significantly reduced, little, or no net GHG emissions
- High-quality fuels or other high-energy density and transportable carriers of energy with significantly reduced, little, or no net GHG emissions
- Feedstocks, resources or material inputs to economic activities, which may be produced through processes or complete resource cycles with significantly reduced, little or no net GHG emissions
- Improved processes and infrastructure for using GHG-free fuels, power, materials, and feedstocks
- CO_2 capture, permanent storage (sometimes referred to as sequestration), and biological uptake
- Technologies that reduce, control or eliminate emissions of non-CO_2 GHGs
- Advances in sciences of remote sensing and other monitoring, measurement and verification technologies, including data systems and inference methods
- Technologies that substantially reduce GHG-intensity
- Voluntary government/industry programs designed to directly reduce GHG emissions
- Programs that result in energy efficiency improvements through grants or direct technical assistance.

[37] In this context, "research, development, demonstration, and deployment activities" is defined as: applied research; technology development and demonstration, including prototypes, scale-ups, and full-scale plants; technical activities in support of research objectives, including instrumentation, observation and monitoring equipment and systems; research and other activities undertaken in support of technology deployment, including research on codes and standards, safety, regulation, and on understanding factors affecting commercialization and deployment; sup-porting basic research addressing technical barriers to progress; activities associated with program direction; and activities such as voluntary partnerships, technical assistance/capacity building, and technology demonstration programs that directly reduce greenhouse gas emissions in the near and long term.

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Page 15 – Geologic Sequestration drawing; Artist's Concept of FutureGen: U.S. Department of Energy; Healthy Forest: Courtesy of DOE/NREL, Credit – U.S. Forest Service

Page 16 – Capstone MicroTurbine™ Model 330: Courtesy of DOE/NREL, Credit – Capstone Turbine Corporation; SF_6 Alternative Cover Gas Technology, 3M ™ Performance Materials Division; Thermal Oxidation of Ventilation Air Methane Using Megtec's Flow Reversal Reactor at CONSOL Energy, BHP Billiton Ltd; Cow: Getty Images

Page 17 – Tractor, applying soil conservation methods: Getty Images

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